

Comparative Analysis of the Phyto-compounds Present in the Control and Experimental Peels of *Musa paradisiaca* used for the Remediation of Chromium Contaminated Water

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Abstract : Banana peels are also widely used as bio-adsorbent in the removal of chemicals contaminants and heavy metals from water and soil. GC-MS plays an essential role in the phytochemical analysis and chemo taxonomic studies of medicinal plants containing biologically active components. Intrinsically, with the use of the flame ionization detector and the electron capture detector which have very high sensitivities, Gas chromatography can quantitatively determine materials present at very low concentrations and most important application is in pollution studies. In the present study banana peels were used as bio-adsorbent to remediate the heavy metal contaminated water taken from three different stations located around the industrial belts of Ranipet, Tamilnadu, India. The AAS analysis of the samples shows a decrement of chromium concentration of 98.93%, 96.16% and 96.5% in Station 1, 2 and 3 respectively which proves the efficiency of the powdered peels of *Musa paradisiaca*. The GC-MS analysis of the control and treated peels of *Musa paradisiaca* reveals the presence of phytochemicals like Acetic Acid, 1-Methylethyl Ester, DL-Glyceraldehyde Dimer, N-Hexadecanoic Acid, 3-Decyn-2-Ol, 26-Hydroxy, Cholesterol, Ergost-25-Ene-3,5,6,12-Tetrol, (3.Beta.,5.Alpha.,6.Beta.,12.Beta.), 1-Methylene-2b-Hydroxymethyl-3, and 3-Dimethyl-4b-(3-Methylbut-2-Enyl)-Cyclohexane in the control banana peels. The banana peels which were used for the treatment reveals the changes and alteration of the phytochemicals. It is concluded that the alteration in phytochemicals of the experimental banana peels were due to adsorption of chromium heavy metal from the sample.

Keywords : Bio-adsorbent, Banana peels, GCMS, AAS, Phytochemicals, Heavy metals, Chromium.

Introduction

The non-nutrient plant chemical compounds and bioactive compounds are referred to as phytochemicals.¹⁻³ Applications of phytochemicals have expanded recently, particularly in the fields of nutraceuticals and functional foods.⁴ The importance of phytochemicals for health is highlighted by Asif *et al.*⁵ One of the most significant crops in the world estimated at 72.5 million metric tonnes of bananas are produced globally, of which India contributes 21.77 million metric tonnes.⁶ The fruit peels from this variety that are thrown away make up 18 to 33%

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of the total fruit peel waste. The banana peels are rich in potassium, phosphorus, magnesium, and calcium as well as 52 other chemical components and nutritional goods.⁷ In comparison to the fruit's pulp, banana peels are rich in chemical components that are valued for their anti-fungal and antibacterial activities.^{8,9} The biotechnological manufacture of protein from banana peel waste also produces ethanol, alpha-amylase, and cellulose.¹⁰ According to Kanazawa *et al.*,¹¹ banana peels include a variety of phytochemicals and phytonutrient components, primarily antioxidants. These include anthocyanins, delphinine, catecholamines, beta-carotene, and alpha-carotene.¹¹ In recent years GC-MS studies have been increasingly applied for the analysis of medicinal plants as this technique has proved to be a valuable method for the analysis of non-polar components and volatile essential oil, fatty acids, lipids, and alkaloids.¹²⁻¹⁴ A key use of GC-MS is the monitoring of environmental contaminants. Equipment for GCMS has become less expensive while significantly improving in reliability. In the current study, the effectiveness of using banana peels to remediate chromium-contaminated wastewater was evaluated. The amount of chromium present in the contaminated water before and after the treatment using banana peels were evaluated by using Atomic Absorption

Spectroscopy (AAS) method. Using the GC-MS technique, the Phyto-compound changes in the experimental *Musa paradisiaca* peels were compared to the control.

Experimental

Study Area

Ranipet is located at 12.56 degree Northern latitude and 79.20 Eastern longitudes and is 93 km west of Chennai, it is geographically 25 km away from the northeast of Vellore. Tamil Nadu Chromate Chemicals Limited (Plate 1) is an industry located in the Chennai-Bangalore national highway NH4 near the Ranipet Industrial area, Ranipet District. Topographically the area is sloping towards the south and southeast side which is towards Puliyanankannu and further down to the Palar river. The Palar which is one of the major drinking water sources is running from west to east and is located 4.5 km down the streamline of the site.¹⁵ Tamil Nadu Pollution Control Board (Tamil Nadu Pollution Control Board, unpublished report, 1996) estimated that ~150,000 tons of solid chromium waste accumulated over two decades of plant operation has been stacked in the open yard (stack height varies from 4 to 5 m) on 3.5 ha of land within the Tamil Nadu Chromate and Chemicals Limited (TCCL) premises, Ranipet, Tamil Nadu, India (Plate 1a). The chemicals from that raw ore were getting leached out by rainwater and seeping into the groundwater and affecting the quality of the groundwater.¹⁶ Samples were collected from Station 1 (Stagnant water inside the TCCL), Station 2 (Run off water from the TCCL) and Station 3 (Stagnant water outside the TCCL), Ranipet, TN, India. (Plate 1b).

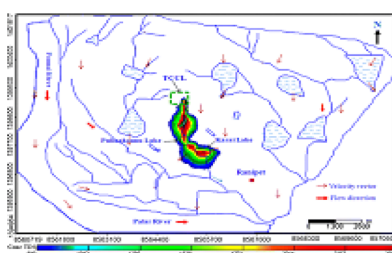


Plate 1. TCCL Topography



Plate 1a. TCCL - Ore Dump Site

Plate 1b. Sample Collection

Preparation of Bio-Adsorbent and Treatment Process

The peels of *Musa paradisiaca* were removed and washed thoroughly in distilled water to remove the external

dirt. The peels were cut into small pieces (Plate 2) and dried under the hot sun for 3 days (Plate 3).¹⁷ Then the dried peels were washed thoroughly in an orbital shaker and dried in a hot air oven for 2 hr at 80°C to remove the moist content. Then the dried peels were powdered blending them in a blender and sieved using 250 microns sieve (Plate 4, 5).¹⁸ Eight grams of powdered peels of *Musa paradisiaca* (Plate 17) were added to 100 mL of Sample 1, 2, and 3 and mixed well using a magnetic stirrer. The treatment setup (Plate 6) was left for 24 hr at room temperature and constant pH.^{19,20} The filtrate was dried and subjected to GC-MS analysis. (Plate 7). The treated water sample was subjected to AAS analysis for determining the adsorption efficiency of the bio-adsorbent and to evaluate the chromium concentration.²¹ AAS is an analytical technique used to determine the concentration of metal ions in a sample.



Plate 2. Fresh Peels of *Mp*



Plate 3. Dried Peels of *Mp*



Plate 4. Powdered Peels of *Mp*



Plate 5. 250 micron Sieve



Plate 6. Treatment setup



Plate 7. Filtration

Preparation of Methanol Extract

The control and the experimental filtrate of the treated banana peel powder was evaporated to dryness and 10 g of powdered peels were dissolved in 100 mL of 100% methanol (CH_3OH) and stirred well using a magnetic stirrer for 3 hours and left overnight. Extracts (50 mL) were then transferred to clean vessels, evaporated to dryness, and dissolved in dimethyl sulfoxide to yield a final concentration of approximately 10 mg/mL and subjected for GC-MS analysis.²²

Table 1. Adsorption Efficiency of Powdered Peels of *Musa paradisiaca* on Heavy Metal Chromium by AAS Method.

Sample	Conc. of Cr (mg/L) before remediation	Conc. of Cr (mg/L) after treatment	Mean adsorption	df	t value	Significance p value
Station 1 Stagnant water inside the TCCL	701.311	7.437 ± 0.3791 (98.93)	0.0288	5	48.053	0.000
Station 2 Run off water from the TCCL	782.047	29.958 ± 0.5315 (96.16)	0.1159	5	138.043	0.000
Station 3 Stagnant water outside the TCCL	849.569	29.629 ± 0.3716 (96.51)	0.1146	5	195.308	0.000

Values in parenthesis () indicates % change over control

Values are Mean, ± SD of 6 individual observation

Significant at $p < 0.005$

GC-MS analysis

GC-MS analysis from the methanol extract of banana peels was carried out in the instrument Perkin Elmer GC Clarus 680, Mass spec Clarus 600 (EI), using the software Turbo Mass ver 5.4.2 and NIST – 2008 library year. The identification of the chemical components was influenced by their GC retention time, percentage composition (area %), and retention indices. The interpretation and identification of their mass spectra were confirmed by the mass spectral incorporated library. The identification was further confirmed by comparing it with the database of the spectrum of known components stored in the GC MS NIST (2008) library.²³ The GC-MS was performed at SIF Laboratory, VIT, Vellore, TN, India.

Result

Table 1 shows the results of the Atomic Absorption Spectroscopy (AAS) analysis performed to estimate the concentration of chromium present in the untreated and treated water samples. 6 individual samples were taken from each Station and experiment was carried out. Mean Value, ± SD and percentage change over control and student t test were done using SPSS version 26. Station 1 shows an initial chromium concentration as 701.311 mg/L. After the treatment, it is estimated as 7.437 mg/L of chromium concentration. Station 2 shows an initial chromium concentration as 782.047 mg/L. After the treatment, it is estimated as 29.958 mg/L of chromium concentration. Station 3 shows an initial chromium concentration as 849.569 mg/L. After the treatment, it is estimated as 29.629 mg/L of chromium concentration.

The exploration of phytochemical screening with methanol extract of *Musa paradisiaca* peels by GCMS is tabulated in Table 2 which reveals the presence of acetic

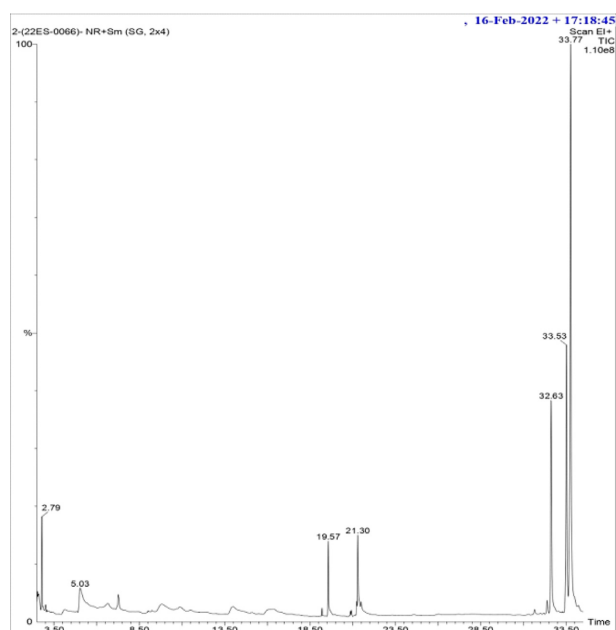
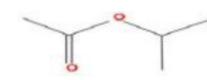
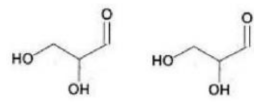
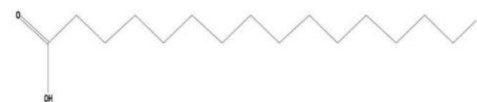
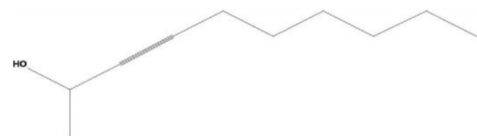
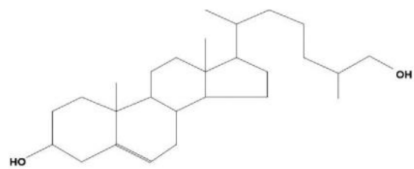
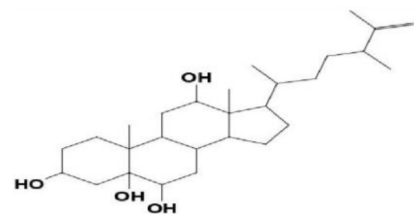
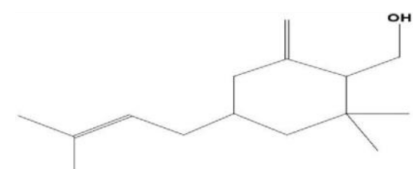


Figure 1. Chromatogram Obtained from the GC-MS with the Extract of Control peels of *Musa paradisiaca*

acid 1-methyl ethyl ester having molecular formula $C_5H_{10}O_2$ with 2.799 min of retention time, DL-Glyceraldehyde dimer having molecular formula $C_6H_{12}O_6$ with 5.039 min of retention time, N-hexadecenoic acid having molecular formula $C_{16}H_{32}O_2$ with 19.570 min of retention time. N-hexadecenoic acid is also called palmitic acid with molecular formula $C_{16}H_{32}O_2$ and 19.570 min retention time. Other compounds include 3-den-2-of having molecular formula $C_{10}H_{18}O$ with 21.2296 min retention time, 2-6-hydroxy cholesterol having a molecular

Table 2. The Phyto-compounds identified by GC-MS in Methanol Extract of Control Peels of *Musa paradisiaca*

S. No	RT	Compound name	Molecular Formula	Molecular weight	Structure
1	2.799	Acetic Acid, 1-Methylethyl Ester	C ₅ H ₁₀ O ₂	102	
2	5.039	D1-Glyceraldehyde Dimer	C ₅ H ₁₀ O ₂	180	
3	19.570	N-Hexadecanoic Acid	C ₁₆ H ₃₂ O ₂	256	
4	21.296	3-Decyn-2-ol	C ₁₀ H ₁₈ O	154	
5	32.626	26-Hydroxy Cholesterol	C ₂₇ H ₄₆ O ₂	402	
6	33.526	Ergost-25-Ene- 3,5,6,12,-Tetrol, (3.Beta.,.5.A1pha.,.6.B eta.,.12.Beta.)-	C ₁₅ H ₂₄ O	220	
7	33.776	1-Methylene-2b Hydroxymethyl-3, 3-Dimethyl-4b-(3- Methylbut-2-Enyl)- Cyclohexane	C ₁₅ H ₂₆ O	222	

formula C₂₇H₄₆O₂ with 32.626 min retention time, Ergost-25-ene-3,5,6,12 Tetrol having molecular formula C₁₅H₂₄O with 33.526 min as retention time and 1-methylene 2b-hydroxy methyl- 3,3-dimethyl-4b cyclohexane having molecular formula C₁₅H₂₆O with 33.776 min retention time. Figure 1 shows a GC-MS Chromatogram of methanol extracts of control peels of *Musa paradisiaca*. The chromatogram shows the RT taken by the analytes to pass through the column and reach the mass spectrometer.

Table 3 shows the main compounds identified by GC-MS in the methanol extract of treated peels of *Musa paradisiaca* in Sample 1 (Treated Peels from Station 1) with five compounds. The bioactive components with their retention time (RT), names of the compounds, and molecular structure of the compound are tabulated. The analysis reveals Undecanoic acid (22.59%), Hexadecanal (39.58%), 4, 22-Stigmastadiene-3-one, 2R-Acetoxyethyl-

1 (26.84%), 3,3-Trimethyl-4T-(3-Methyl-2-Buten-1-yl)-1t-Cyclohexanol (27.02%) and 9, 19-Cycloergost-24(28)-EN-3-ol, 4,14-dimethyl-acetate (3.beta., 4.alpha.)- (100%). Figure 2 shows the Chromatogram of GC-MS analysis of methanol extract of treated peels of *Musa paradisiaca* in Sample 1, at RT 19.910 has 10.457 area%, RT 21.391 has 18.322 area%, RT 27.569 has 12.425 area%, RT 28.039 has 12.508 area% and RT 28.164 has 46.288 area%.

Table 4 shows the main compounds identified by GC-MS in the methanol extract of treated peels of *Musa paradisiaca* in Sample 2 (Treated Peels from Station 2) were eleven compounds. The analysis reveals 4h-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl- (62.39%), Methane carbothiolic acid (50.82%), 2-Amino-octadec-7-ene-1,3-diol butaneboronate (41.46%), Hydroperoxide,1-methylpentyl (21.96%), 2,3-anhydro-d-galactosan (41.30%), 2,3-anhydro-d-galactosan (41.30%), 3-dimethylsilyloxytridecane (78.63%),

Table 3. The Phyto-compounds identified by GC-MS in Methanol Extract of Treated Peels of *Musa paradisiaca* in Sample 1



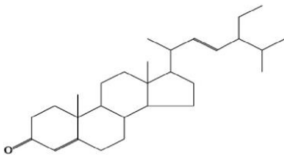
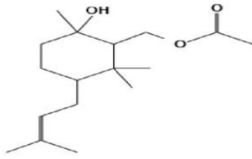
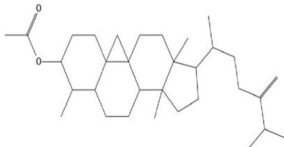
S. No	RT	Compound name	Molecular Formula	Molecular weight	Structure
1	19.910	Undecanoic acid	C ₁₁ H ₂₂ O ₂	186	
2	21.391	Hexadecana	C ₁₆ H ₃₂ O	240	
3	27.569	4,22-Stigmastadiene-3-one	C ₂₉ H ₄₆ O	410	
4	28.039	2R-Acetoxyethyl-1,3,3-Trimethyl-4T-(3-Methyl-2-Buten-1-yl)-Cyclohexanol	C ₁₇ H ₃₀ O ₃	282	
5	28.164	9,19-Cycloergost-24(28)-EN-3-ol, 4,14-dimethyl-acetate (3.beta.,4.alpha.)-	C ₃₂ H ₅₂ O ₂	468	

Table 4. The Phyto-compounds identified by GC-MS in Methanol Extract of Treated Peels of *Musa paradisiaca* in Sample 2

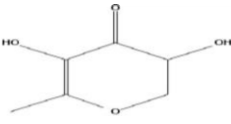

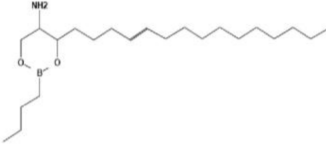
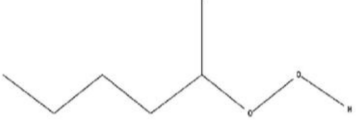
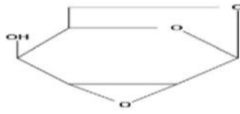
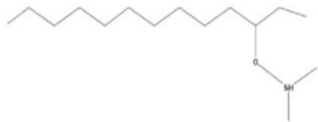
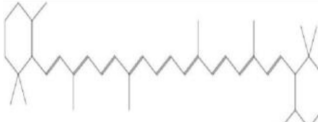
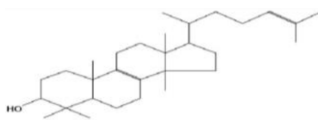
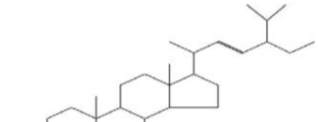
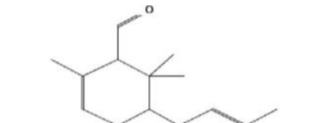
S. No	RT	Compound name	Molecular Formula	Molecular weight	Structure
1	14.613	4h-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl-	C ₆ H ₈ O ₄	144	
2	16.494	Methane carbothiolic acid	C ₂ H ₄ OS	76	
3	18.270	2-Amino-octadec-7-ene-1,3-diol butaneboronate	C ₂₂ H ₄₄ O ₂ NB	365	
4	19.260	Hydoroperoxide,1-methyl-pentyl	C ₆ H ₁₄ O ₂	118	
5	20.181	2,3-anhydro-d-galactosan	C ₆ H ₈ O ₄	114	
6	21.766				

Table 4. Continued

S. No	RT	Compound name	Molecular Formula	Molecular weight	Structure
7	25.052	3-dimethylsilyloxytridecane	C ₁₅ H ₃₄ OSi	258	
8	27.659	.Beta.carotene	C ₄₀ H ₅₆	536	
9	27.744	Lanosterol	C ₃₀ H ₅₀ O	426	
10	28.254	Stigmasterol	C ₂₉ H ₄₈ O	412	
11	28.434	1-formyl-2,2,6-trimethyl-3-cis-(3-methylbut-2-enyl)-5-cyclohexene	C ₁₅ H ₂₄ O	220	

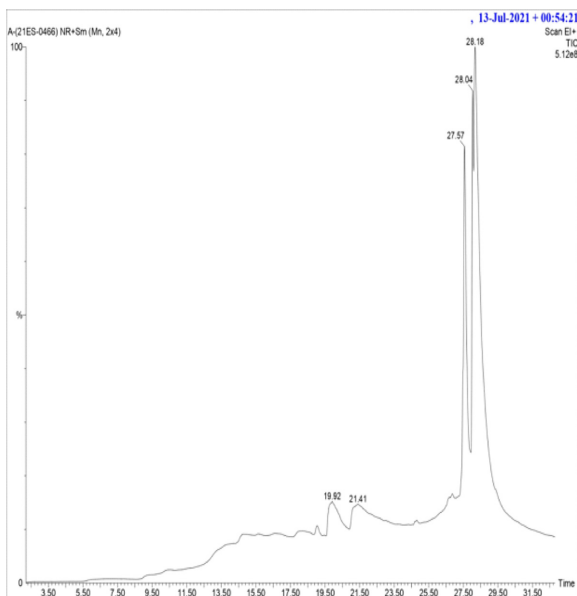


Figure 2. Chromatogram Obtained from the GC-MS with the Extract of Control peels of *Musa paradisiaca* Treated in Sample 1

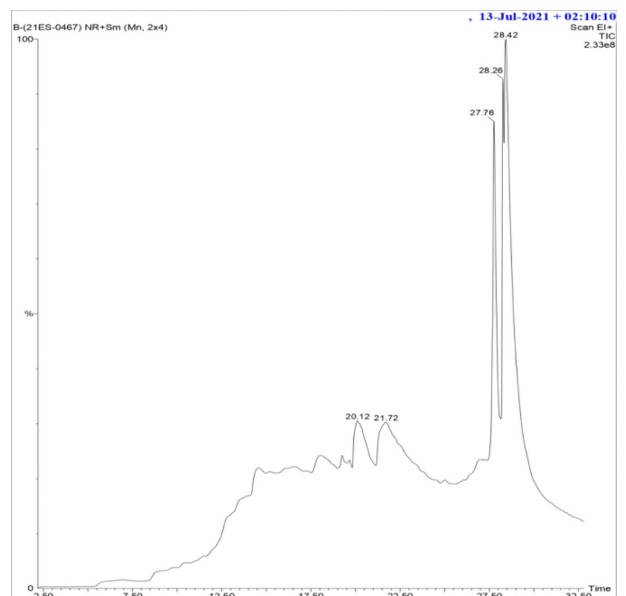


Figure 3. Chromatogram Obtained from the GC-MS with the Extract of Control peels of *Musa paradisiaca* Treated in Sample 2

Beta carotene (23.02%), Lanosterol (36.28%), Stigmasterol (20.90%) and 1-formyl-2,2,6-trimethyl-3-cis-(3-methylbut-2-enyl)-5-cyclohexene (100%). Figure 3 GC-MS Chromatogram

of methanol extracts of treated peels *Musa paradisiaca* in Sample 2 showing the peak retention times and the peak heights.

Table 5. The Phyto-compounds identified by GC-MS in Methanol Extract of Treated Peels of *Musa paradisiaca* in Sample 3

S. No	RT	Compound name	Molecular Formula	Molecular weight	Structure
1	27.649	9,19-Cycloergost-24 (28)-En-3-O1,4,14-Dimethyl-,Acetate,(3.Beta.,4.Alpha.,5.Alpha)	C ₃₂ H ₅₂ O ₂	468	
2	27.764	4,5-Secocholest-6-En-4-Oic Acid,5-Oxo	C ₂₇ H ₄₄ O ₃	416	
3	28.239	22-Stigmasten-3-One	C ₂₉ H ₄₈ O	412	
4	28.414	2-Methyl-3-(3-Methyl-But-2-Enyl)-2-(4-Methyl-Pent-3-Enyl)-Oxetane	C ₁₅ H ₂₆ O	222	

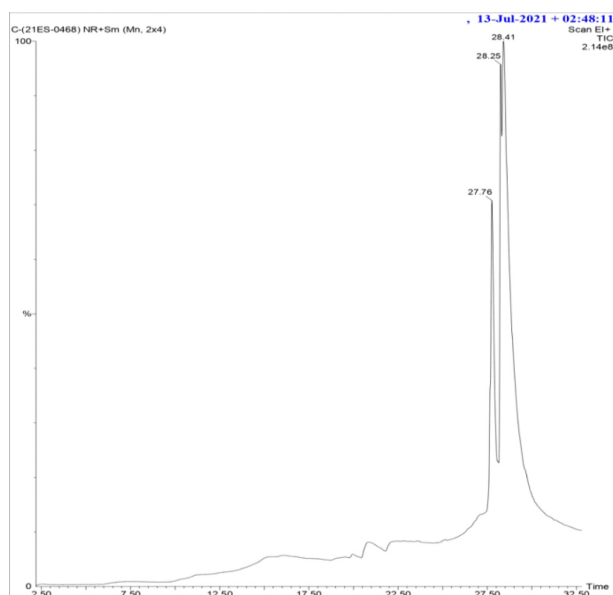
**Figure 4.** Chromatogram Obtained from the GC-MS with the Extract of Control peels of *Musa paradisiaca* Treated in Sample 3

Table 5 shows the main compounds identified by GC-MS in the methanol extract of treated peels of *Musa paradisiaca* in Sample 3 (Treated Peels from Station 3) with five compounds. The analysis reveals 9,19-cycloergost – 24

(28)-en-3-ol,4,14-dimethyl-acetate, (3.beta.,4.alpha.,5.alpha) (22.59%), 4,5-secocholest-6-en-4-oic acid,5-oxo (39.58%), 22-stigmasten-3-one (26.84%), 2-methyl-3-(3-methyl-but-2-enyl)-2-(4-methyl-pent-3-enyl)-oxetane (27.02%). Figure 4 showed a GC-MS Chromatogram of methanol extracts of treated peels *Musa paradisiaca* in Sample 3 showing the peak retention times and the peak heights.

Discussion

Biowaste of plants is the source of potentially bioactive compounds which are useful in all areas. The biological and pharmacological properties are very vital and still many are unknown.²³ Effective use of peels of *Musa paradisiaca* for the remediation of chromium-contaminated water paves the way to reclaim the environment that is lost due to heavy metal pollution. The ASS result shows there was a decrement in chromium concentration in Samples 1, 2, and 3 which proves the efficiency of the powdered peels of *Musa paradisiaca*. The adsorption efficiency of the bio-adsorbent was 98.93%, 96.16%, and 96.5% in stations 1, 2, and 3 respectively. Methanol is the most commonly used extraction solvent due to its high polarity which could produce high extraction yields. Methanol usually enriches more hydrophilic molecules than hydrophobic molecules.²⁴ The exploration of phytochemical screening with methanol

extract of control *Musa paradisiaca* peels reveals the presence of Glyceraldehyde an aldotriose comprising propanal having hydroxy groups at the 2- and 3-positions. Most sugars found in nature are D-sugars, which are related to D glyceraldehyde, whilst most amino acids found in proteins belong to the L-stereochemical series related to L-glyceraldehyde.²⁵ Palmitic acid is a saturated fatty acid used in the production of soap and renovates the skin.²⁶ These are the organic compounds required for the normal growth and maintenance of life of animals, including humans, and are essential for the transformation of energy and regulation of the metabolism of structural units.²⁷

Acetic acid 1-methyl ethyl ester having molecular formula $C_5H_{10}O_2$ with 2.799 min of retention time in which the methyl esters are found to be an excellent solvents with low volatility and good solubility. They are widely used to replace mineral spirits in the textile, screen ink industry, and graphics arts industries. Their main benefits are low volatility and flammability, low toxicity, and environmental compatibility. They have also been used in paint removal products in both consumer and industrial applications. Methyl esters have also found applications in the removal and recovery of spilled crude oil and other petroleum products from both coastal and inland spill sites.²⁸ It has been reported that estragole has many biological effects including antioxidant and antimicrobial activities. The hexadecanoic acid ethyl ester can be an antioxidant, hypocholesterolemic, nematicide, pesticide,

and lubricant activities, and hemolytic 5 – alpha is a reductase inhibitor.²⁹ It is found that it has been used as an antioxidant in the oils and fats in lipid oxidation and also as an agent in foodstuffs and health functional ingredients in various foods and dietary supplements.

The exploration of phytochemical screening with methanol extract of *Musa paradisiaca* peels reveals the presence of 2-butanone, 4-(acetyloxy)- having molecular formula $C_6H_{10}O_3$ with 2.698 min of retention time, Benzene Aceto nitrile 4-hydroxy having molecular formula C_8H_7ON with 14.088 min of retention time, Beta.-d-glucopyranose, 1,6-anhydro- having molecular formula $C_6H_{10}O_5$ with 14.573 min of retention time, D-glycero-d-tallo-heptose having molecular formula $C_7H_{14}O_7$ with 15.829 min of retention time, 1,5,9-undecatriene, 2,6,10-trimethyl-, (z)- having molecular formula $C_{14}H_{24}$ with 17.985 min of retention time, N-hexadecanoic acid having molecular formula $C_{16}H_{32}O_2$ with 19.685 min of retention time, 9-hexadecenoic acid having molecular formula $C_{16}H_{30}O_2$ with 21.471 min of retention time, 2-Piperidinone, n-[4-bromo-n-butyl]- having molecular formula $C_9H_{16}ONBR$ with 21.661 min of retention time, Glucitol, 6-o-nonyl- having molecular formula $C_{15}H_{32}O_6$ with 24.602 min of retention time, 2-Tert-butyl-4,6-bis (3,5-di-tert-butyl-4-hydroxybenzyl) phenol having molecular formula $C_{40}H_{58}O_3$ with 29.805 min of retention time and 1-hexyl-2-nitrocyclohexane having molecular formula $C_{12}H_{23}O_2N$ with 32.256 min of retention time. However, in single metal solutions, ions with larger ionic

Table 6. Comparison of Phyto-compounds Present in the Control and Experimental Peels of *Musa paradisiaca* in Sample 1, 2, and 3 by GC-MS

S.No	RT	Compounds present in the Control peels	Compounds present in the Experimental Peels in Sample 1	Compounds present in the Experimental Peels in Sample 2	Compounds present in Experimental Peels in Sample 3
1	2.799	Acetic Acid, 1-Methyl-ethyl Ester	-	-	-
2	5.039	D1-Glyceraldehyde Dimer	-	-	-
3	14.613	-	-	4h-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl	-
4	16.494	-	-	Methane carbothiolic acid	-
5	18.270	-	-	2-Amino-cotadec-7-ene-1,3-diol butaneboronate	-
6	19.260	-	-	Hydroperoxide, 1-methylpentyl	-
7	19.570	N-Hexadecanoic Acid	-	-	-
8	19.910	-	Undecanoic acid	-	-
9	20.181	-	-	2,3-anhydro-d-galactosan	-

Table 6. Continued

S.No	RT	Compounds present in the Control peels	Compounds present in the Experimental Peels in Sample 1	Compounds present in the Experimental Peels in Sample 2	Compounds present in Experimental Peels in Sample 3
10	21.296	3-Decyn-2-O1	-	-	-
11	21.391	-	Hexadecanal	-	-
12	21.766	-	-	2,3-anhydro-d-galactosan	-
13	25.052	-	-	3-dimethyl silyloxy-tridecane	-
14	27.569	-	4,22-Stigmastadiene-3-one	-	-
15	27.649	-	-	-	9,19-Cycloergost-24(28)-En-3-O1,4,14-Dimethyl-,Acetate,(3.Beta.,4.Alpha.,5.Alpha)
16	27.659	-	-	Beta.carotene	-
17	27.744	-	-	Lanosterol	-
18	27.764	-	-	-	4,5-Secocholest-6-En-4-Oic Acid,5-Oxo
19	28.039	-	2R-Acetoxyethyl-1,3,3-Trimethyl-4T-(3-Methyl-2-Buten-1-yl)-1t-Cyclohexanol	-	-
20	28.164	-	9, 19-Cycloergost-24(28)-EN-3-ol, 4,14-dimethyl-acetate (3.beta., 4.alpha.)-	-	-
21	28.239	-	-	-	22-Stigmasten-3-One-
22	28.254	-	-	Stigmasterol	-
23	28.414	-	-	-	2-Methyl-3-(3-Methyl-But-2-Enyl)-2-(4-Methyl-Pent-3-Enyl)-Oxetane
24	28.434	-	-	1-formyl-2,2,6-trimethyl-3cis-(3-methylbut-2-enyl)-5-cyclohexene	-
25	32.626	26-Hydroxy Cholesterol	-	-	-
26	33.526	Ergost-25-Ene-3,5,6,12-Tetrol, (3.Beta.,5.Alpha.,6.Beta., 12.Beta.)-	-	-	-
27	33.776	1-Methylene-2b-Hydroxymethyl-3,3-Dimethyl-4b-(3-Methyl-but-2-Enyl)-Cyclohexane	-	-	-

radii are better adsorbed than those with less ionic radii.³⁰ The banana peels which were used for the treatment reveal changes and alterations of the phytochemicals in all three experimental banana peels.

The alteration in the phytochemicals of the experimental banana peels was due to the adsorption of chemical contaminants from the sample. Further, while comparing the GC-MS analysis of the control and the experimental banana peels it is evidenced that the adsorption of chemical compounds was found effective, and binding the adsorbed chemicals, changing the chemical composition of phytochemicals which is tabulated in Table 6. The functional groups that were active in removing Chromium from water were the carboxylic and amine groups and the alterations in the phytochemicals were due to the adsorption of heavy metal chromium. The anionic ligands present on the cell wall such as carboxyl, amine, hydroxyl, carbonyl, sulfhydryl and phosphoryl groups immobilizes the metal ions³¹ and then uptake occurs³² which was evidenced.

Conclusion

Waste banana peels were used as a bio-adsorbent for the remediation of the chromium-contaminated wastewater collected from the industrial area of Ranipet District, TN, India and found to be very best, low cost and effective bio-adsorbent to remediate the heavy metal chromium. The compared results of control and experiment bio-adsorbent, peels of *Musa paradisiaca* showed the phytochemicals alterations due to the adsorption of chromium heavy metal from the sample which evidences the adsorption capacity of banana peels. This cost-effective, eco-friendly method could be used for the remediation of chromium-polluted water for the restoration of the polluted water bodies.

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