A Study on the Water and Soil Resources Surrounding the Pachanady Dump Yard, Mangalore and the Proposal of a Biochar-Chitosan Composite Membrane for a Landfill Lining

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Abstract – *Solid waste disposal is a major concern in numerous developing countries. It is observed that the solid wastes are generally disposed off in dump yard where they are likely to contaminate the ground water and soil strata due to a phenomenon of leachate infiltration. This project mainly deals with the assessment of ground water and soil conditions that are suspected to contamination in and around the Pachanady Dump yard, Mangalore. Studies were conducted on the ground water and the soil samples collected from various points by means of certain laboratory tests followed by the analysis of the same. The methodology involved the collection of ground water and soil sample by sampling technique circumferentially and radially around the dump yard and then it was subjected to various tests. The test reports revealed that the groundwater and soil samples were not adversely affected with contamination and the results were within the specified code limits. However, in the case of future contamination risks, the development of novel membrane is proposed that comprises a composite of Biochar and Chitosan – obtained from shrimp shell and skeleton. The membrane is expected to adsorb the heavy metal ions on the surface and immobilize its movement there by preventing leachate infiltration.*

***Key Words*: Leachate infiltration, Heavy metal ion contamination, Biochar, Chitosan**

1. INTRODUCTION

Disposal of solid waste is defined as placement of waste so that it no longer impacts society or the environment. The wastes are either assimilated so that they can no longer be identified in the environment, as by incineration to ash, or they are hidden well enough so that they cannot be readily found. Solid waste may also be processed so that some of its components may be recovered and used again for a beneficial purpose. Collection, disposal, and recovery are all part of the total solid waste management system.

1.1 Objectives of the Study

i. To perform a Reconnaissance Survey i.e., to study the surroundings of the Pachanady Dump yard and assess the present scenario of the ill effects faced if any by the residents.
ii. To collect soil and water samples around the landfill and test it for the presence of heavy metal contamination.
iii. To propose a Biochar-Chitosan Composite membrane for a landfill lining to minimize the leachate infiltration

1.2 About the Dump yard

The landfill, which is the main dump yard in Mangalore is almost about 50 years old and were approximately about 70 acres of land. Residents in the area have often spontaneous fire in the landfill and foul odour emanating from it. Without any qualms, the living conditions around the dump yard is quite unfavourable and the locations may also be susceptible to diseases due to the unhealthy atmosphere dump yard lately.

Mangalore generates around 250 tones of solid waste every out of which 200 tones is collected and disposed into the landfill located at Vamanjoor at a distance of 15km from the city. The dumping yard has an area of 77 acres which is poorly managed. Vamanjoor is along the national highway (NH13) and is a home for many educational institutes.

The main waste generated is from homes, markets from agricultural products, retail and commercial markets, slaughter houses and industries. This dump yard was started in the early 80's. This dump yard has not only been a source of air pollution but also has contaminated the groundwater in the vicinity. There are close to 1250 families which live within a proximity of 500m from the dump yard.

Leachate percolation has resulted in groundwater turning black and smelling foul in areas like Jyothinagar and Santhoshnagar which are in the vicinity of Vamanjoor. This effect is compounded during the monsoons. Respondents in the study area reported loss of appetite, vomiting and giddiness. Local school authorities reported that school children from Vamanjoor area suffer frequently from health disorders. Hence, the intensions behind the study is to evaluate the extent of pollution in the area and identifying individual pollutant concentrations, and thereby the impact of landfill on ground water contamination.

1.3 The Dump yard Hazard

Woefully, there was a recent sliding of a huge heap of wastes due to shear failure as a result of copious rainfall on 9th August 2019, that demolished at least twenty to twenty-five households that made a living. In addition to this, the torrential rain also caused the destruction of about three acres of agricultural land which comprised of numerous arecanut and coconut tress located on the downstream of the landfill in the Mandara area. The occupants have shifted to a safer place with suitable compensation after the menace.

Fig – 1: Destructed house

2. SAMPLE COLLECTION

The 77 acres of the landfill area was surrounded by a significant number of ground water source like that of wells and bore wells which was once used by the localities for various domestic purposes. Hence these sites ultimately turned out to be the potential sites for the collection of water samples. The samples were collected radially and circumferentially around the landfill by means of suitable sampling techniques.

2.1 Location of Sites for Water Sample Collection

i. **KARUNAKARA KANJIRADI (Ground Water Source):** This ground water source was located at a dwelling of a localite.

   The geographical location of this particular site is 12°54'35"N, 74°52'37"E.

ii. **KARUNAKARA KANJIRADI (Surface Water Source):** This particular source of surface water served as a major source of water for the irrigation purposes for the arecanut farm owned by the owners. The source of water is very close to the landfill and is just a few meters away from the landfill.

   The geographical location of the source is 12°554'37"N, 74°52'35"E.

iii. **MANDARA LOKANATHA (Surface Water Source):** This particular source of surface water is about 25m away from the landfill area. The surface of this water source clearly showed the presence of oil, grease deposition leading to the formation of a slimy layer. These reasons in addition to suspected contamination from the landfill had made the source unfit for any further consumption. The aquatic life in the source has also deteriorated in the course of time.

The geographical location of the following is 12°55'34"N, 74°53'04"E.

Collection of water samples around the dump yard from Ground water and Surface water sources involved the following procedure:

i. After the location of sites for sample collection was finalized, sample collection was succeeded.
ii. Samples from the wells (groundwater sources) were collected by means of pots and then immediately transferred to airtight cans with the shortest time gap to avoid contamination.
iii. The collection of samples from the surface water was also done in the same manner. Finally, the collected samples were sent to laboratory for testing of heavy metals and certain physical parameter test was also conducted.

2.2 Location of Sites for Soil Sample Collection

Collection of soil samples within the landfill involved the following procedure:

i. Initially the sites for soil collected were plotted all over the 77acres of land.
ii. Pool sampling was considered as sample testing of individual samples was not cost effective.
iii. About 50cm was dug into the soil with the help of a suitable instrument and then the soil was extracted at each of the locations.
iv. The pool sampling involved collection of about 4 samples around 25 acres of land each and then mixing the individual samples to form a homogenous mixture.
v. The homogenous mixture was then packed to bags and covered airtight and then sent to the laboratory for testing of heavy metal contamination.

Fig – 2: Soil sample collection

3. RESULTS AND DISCUSSIONS

The soil and water samples collected were basically tested for the presence of heavy metals in a lab named Hubert Enviro Care Systems (P) Ltd., Industrial Estate, Baikampady, Mangalore.

3.1 Water Sample Test Results

i. **Sample Description: Karunakara Kanjiradi – Surface Water Souce-1**

Table - 1: Results of Surface Water Source-1

Sl. No	Parameters	Units	Results	IS:10500-2012	
				Acceptable	Permissible
1	Iron as Fe	mg/l	8.75	0.3	
2	Aluminum as Al	mg/l	0.03	0.03	0.2
3	Boron as B	mg/l	0.1	0.5	1
4	Hexavalent Chromium	mg/l	0.01	NA	NA
5	Zinc as Zn	mg/l	0.1	5	15
6	Chromium as Cr	mg/l	0.01	0.05	
7	Copper as Cu	mg/l	0.01	0.05	1.5
8	Manganese as Mn	mg/l	0.05	0.1	0.3
9	Cadmium as Cd	mg/l	0.001	0.003	
10	Lead as Pb	mg/l	0.005	0.01	
11	Selenium as Se	mg/l	0.005	0.01	
12	Arsenic as As	mg/l	0.005	0.01	0.05
13	Mercury as Hg	mg/l	0.001	0.001	
14	Nickel as Ni	mg/l	0.01	0.02	
15	Antimony as Sb	mg/l	0.002	NA	NA
16	Silver as Ag	mg/l	0.01	0.1	
17	Molybdenum as Mo	mg/l	0.01	0.07	
18	Beryllium as Be	mg/l	0.01	NA	NA
19	Lithium as Li	mg/l	0.01	NA	NA

20	Cobalt as Co	mg/l	0.01	NA	NA
21	Vanadium as V	mg/l	0.01	NA	NA
22	Strontium as Sr	mg/l	0.01	NA	NA

ii. Sample Description: Karunakara Kanjiradi – Ground Water Souce-1

Table - 2: Results of Ground Water Source-1

Sl. No	Parameters	Units	Results	IS:10500-2012	
				Acceptable	Permissible
1	Iron as Fe	mg/l	0.16	0.3	
2	Aluminum as Al	mg/l	0.03	0.03	0.2
3	Boron as B	mg/l	0.1	0.5	1
4	Hexavalent Chromium	mg/l	0.01	NA	NA
5	Zinc as Zn	mg/l	0.1	5	15
6	Chromium as Cr	mg/l	0.01	0.05	
7	Copper as Cu	mg/l	0.01	0.05	1.5
8	Manganese as Mn	mg/l	0.05	0.1	0.3
9	Cadmium as Cd	mg/l	0.001	0.003	
10	Lead as Pb	mg/l	0.005	0.01	
11	Selenium as Se	mg/l	0.005	0.01	
12	Arsenic as AS	mg/l	0.005	0.01	0.05
13	Mercury as Hg	mg/l	0.0001	0.001	
14	Nickel as Ni	mg/l	0.01	0.02	
15	Antimony as Sb	mg/l	0.002	NA	NA
16	Silver as Ag	mg/l	0.001	0.1	
17	Molybdenum as Mo	mg/l	0.01	0.07	
18	Beryllium as Be	mg/l	0.01	NA	NA
19	Lithium as Li	mg/l	0.01	NA	NA
20	Cobalt as Co	mg/l	0.01	NA	NA
21	Vanadium as V	mg/l	0.01	NA	NA
22	Strontium as Sr	mg/l	0.01	NA	NA

iii. Sample Description: Devaki Nilaya – Ground Water Souce-2

Table - 3: Results of Ground Water Source-2

Sl. No	Parameters	Units	Results	IS:10500-2012	
				Acceptable	Permissible
1	Iron as Fe	mg/l	0.27	0.3	
2	Aluminum as Al	mg/l	0.03	0.03	0.2
3	Boron as B	mg/l	0.1	0.5	1
4	Hexavalent Chromium	mg/l	0.01	NA	NA
5	Zinc as Zn	mg/l	0.1	5	15
6	Chromium as Cr	mg/l	0.01	0.05	
7	Copper as Cu	mg/l	0.01	0.05	1.5
8	Manganese as Mn	mg/l	0.05	0.1	0.3
9	Cadmium as Cd	mg/l	0.001	0.003	
10	Lead as Pb	mg/l	0.005	0.01	
11	Selenium as Se	mg/l	0.005	0.01	
12	Arsenic as AS	mg/l	0.005	0.01	0.05
13	Mercury as Hg	mg/l	0.0001	0.001	
14	Nickel as Ni	mg/l	0.01	0.02	
15	Antimony as Sb	mg/l	0.002	NA	NA
16	Silver as Ag	mg/l	0.001	0.1	
17	Molybdenum as Mo	mg/l	0.01	0.07	
18	Beryllium as Be	mg/l	0.01	NA	NA
19	Lithium as Li	mg/l	0.01	NA	NA
20	Cobalt as Co	mg/l	0.01	NA	NA
21	Vanadium as V	mg/l	0.01	NA	NA
22	Strontium as Sr	mg/l	0.01	NA	NA

3.2 Soil Sample Test Results

i. Sample Description: Dumping Area – S1

Table - 4: Dumping Area – S1

Sl.No	Parameters	Units	Results
1	Chromium	mg/kg	0.1
2	Lead	mg/kg	1.67
3	Cadmium	mg/kg	0.1
4	Boron	mg/kg	0.1
5	Aluminium	mg/kg	460.32
6	Mercury	mg/kg	0.1
7	Nickel	mg/kg	1.595
8	Arsenic	mg/kg	0.1
9	Selenium	mg/kg	0.1
10	Hexavalent Chromium	mg/kg	0.1
11	Molybdenum	mg/kg	0.623
12	Vanadium	mg/kg	0.1
13	Cobalt	mg/kg	0.748
14	Antimony	mg/kg	0.1
15	Beryllium	mg/kg	0.1
16	Zinc	mg/kg	4.613
17	Manganese	mg/kg	75.407
18	Copper	mg/kg	2.294
19	Iron	mg/kg	146.127
20	Lithium	mg/kg	0.324
21	Strontium	mg/kg	1.79
22	Silver	mg/kg	0.398

ii. Sample Description: Dumping Area – S2

Table - 5: Dumping Area – S2

Sl.No	Parameters	Units	Results
1	Chromium	mg/kg	4.146
2	Lead	mg/kg	0.799
3	Cadmium	mg/kg	0.1
4	Boron	mg/kg	0.1
5	Aluminium	mg/kg	1274.22
6	Mercury	mg/kg	0.1
7	Nickel	mg/kg	4.046
8	Arsenic	mg/kg	0.324
9	Selenium	mg/kg	0.1
10	Hexavalent Chromium	mg/kg	3.241
11	Molybdenum	mg/kg	0.1
12	Vanadium	mg/kg	2.322
13	Cobalt	mg/kg	1.024
14	Antimony	mg/kg	0.1
15	Beryllium	mg/kg	0.1
16	Zinc	mg/kg	4.221
17	Manganese	mg/kg	168.69
18	Copper	mg/kg	1.623
19	Iron	mg/kg	1896.46
20	Lithium	mg/kg	0.47
21	Strontium	mg/kg	0.974
22	Silver	mg/kg	5.520

iii. Sample Description: Dumping Area – S3

Table - 6: Dumping Area – S3

Sl.No	Parameters	Units	Results
1	Chromium	mg/kg	2.298
2	Lead	mg/kg	0.524
3	Cadmium	mg/kg	0.1
4	Boron	mg/kg	0.1
5	Aluminium	mg/kg	854.38
6	Mercury	mg/kg	0.1
7	Nickel	mg/kg	3.022
8	Arsenic	mg/kg	0.224
9	Selenium	mg/kg	0.1
10	Hexavalent Chromium	mg/kg	1.985
11	Molybdenum	mg/kg	0.1
12	Vanadium	mg/kg	1.199
13	Cobalt	mg/kg	0.999
14	Antimony	mg/kg	0.1
15	Beryllium	mg/kg	0.1
16	Zinc	mg/kg	3.422
17	Manganese	mg/kg	155.50
18	Copper	mg/kg	7.069
19	Iron	mg/kg	1074.24
20	Lithium	mg/kg	0.349
21	Strontium	mg/kg	1.74
22	Silver	mg/kg	0.1

4. PROPOSAL OF A BIOCHAR CHITOSAN COMPOSITE MEMBRANE

From the above test results, the water and soil samples around the dump yard have proven to show high concentrations of a few heavy metal ions whereas the rest of the heavy metal ions are fortunately within the permissible limits.

However, the case may not be the same in the near future. The soil and groundwater sources surrounding the landfill are definitely exposed to a very high risk of contamination. It is very necessary to limit the future damage that can occur from the continued dumping of wastes without any lining to soil as of now.

Thus. a landfill lining has to be well developed in order to maintain a healthy dumping atmosphere.

The landfill lining has membrane layer as one of its major constituent and hence we have proposed a new type of composite membrane that basically involves the combination of Biochar and Chitosan as the major raw materials.

The following membrane is expected to adsorb the heavy metal ions on the surface thereby inhibiting the movement. The immobilization of the heavy metals on the surface prevent the leaching of the hazardous metal ions to the deeper strata of soil and water thereby minimizing the contamination of these sources.

4.1 Biochar

Biochar is a charcoal like substance that is made by burning organic material at a temperature of 300 to 1000°c from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis. Although it looks lot like a common charcoal, biochar is produced using a specific process to reduce contamination an safely store carbon. During pyrolysis organic materials, such as coconut husk, petiole and coir pith, are burned in a container with very little oxygen. As the materials burn, they release little to no contaminating fumes. During the pyrolysis process, the organic material is converted into biochar, a stable form of carbon that can't easily escape to atmosphere.

Biochar Production Procedure

i. The process involved sun drying of the coconut biomass residues until the moisture contents of feedstocks reduced considerably.
ii. Among the different substrates tried, the coconut leaf petiole was chopped into 1015cm pieces before pyrolysis, whereas, all others were used as such.
iii. The dried feedstock was then layered into the kiln and heated at fluctuating temperatures of 350-450°c range for 2-6h for producing the biochar. The colour of the smoke was used as visual indicator of the process of carbonization. No harvesting of the volatiles released during the process was adopted.
iv. Once the material was carbonized (turned black colour) through partial combustion, water was sprinkled over the hot biochar and allowed to cool.
v. The cooled biochar was then crushed to coarse particles by beating with a wooden mallet and stored.
vi. Portions of biochar that had uncarbonized knots evident during crushing, were discarded.

The particle size of biochar ranged between 1.5 and 3.0mm with coir pith biochar having more percentage of smaller and uniform sized particles. A minimum of three batches were run for each type of substrate tried in this study.

Biochar as a membrane

Heavy metals are really the problem in the dump yard water percolating through the leachate carries the heavy metals to the soils and groundwater which pollutes both the soil and the water. Great efforts have been made to use the economically efficient and unconventional absorbents to absorb heavy metals from aqueous solution, such as plant wastes and agricultural waste.

Biochar mixed with chitosan after crosslinking can be casted into membranes, beads and solutions which can effectively utilized as an absorbent for metal ion uptake. Keeping these facts in consideration, the present study was undertaken with the objective to determine the effect of various proportions of biochar-modified chitosan membrane on absorption. This membrane is best utilized for adsorption of heavy metals.

4.2 Chitosan

The most important derivative of chitin is chitosan obtained by deacetylation of chitin in the solid state under alkaline conditions or by enzymatic hydrolysis in the presence of chitin deacetylation. Because of the semi crystalline morphology of chitin and chitosan obtained by a solid-state reactions have a heterogeneous distributions of acetyl groups along the chains.

When the degree of deacetylation of chitin reaches about 50% it becomes soluble in aqueous acidic media and is called as chitosan. In the solid state, chitosan is semi crystalline polymer. Its morphology has been investigated and many polymorphs are mentioned in the literature. Single crystals of chitosan were obtained using fully deacetylated chitin of low molecular weight.

A highly deacetylated polymer has been used to explore methods of characterization. The solution properties of a chitosan depend not only on its average DA, but also on the distribution of the acetyl groups along the main chain in addition of molecular weight. Chitosan is used to prepare hydrogels, films, fibers or sponges, most of the material are used in the biomedical domain, for which biocompatibility is essential. Chitosan is much easier to process than chitin, but the stability of chitosan material is lower.

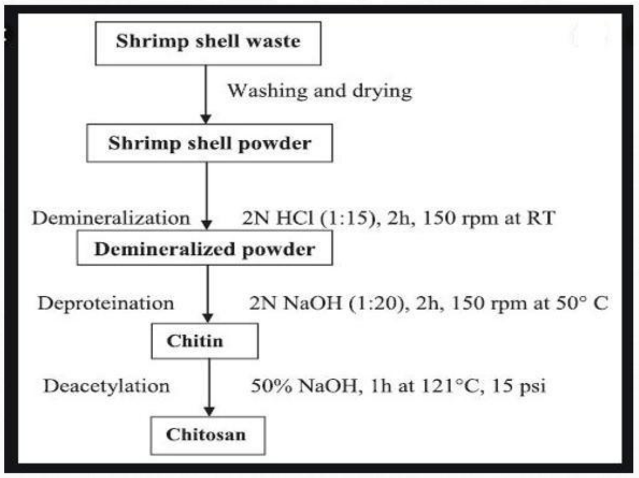

Fig – 3: Chitosan Production Procedure

Chitosan as a Membrane

Chitosan exhibits a unique set of properties that makes this polymer a great candidate for the development of water treatment process. Among them, the most relevant are its high biodegradability, low toxicity, low price and natural availability. The weaknesses exhibited by this biopolymer however derive from its low acid stability, poor mechanical properties, low thermal stability resistance to mass transfer, low porosity and surface areas. In order to overcome the drawbacks exhibited by chitosan, a large amount of effort has been devoted to the development of physicochemical modification methods to include different types of functionalization in the polymer. Chemical modification also has been carried out. Chitosan has revealed a large potential in the detoxification of polluted effluents. This biopolymer on itself and chitosan-based materials have not only shown high capacity to remove a variety of toxic metal but also have demonstrated a large potential to remove other concerning in organic species from water.

5. CONCLUSIONS

i. Despite the various new technologies that are emerging for solid waste disposal, landfilling still remains the most common solution. The establishment and closure of landfills could pose a potential hazard to ground water, due to leachate seepage, and air quality due to gases released.

ii. Improper management of solid waste has created serious environmental problems i.e. pollution of ground and surface water because of leaching and polluted water flowing from waste disposal sites cause serious pollution of water supply, open burning of waste cause air pollution, causing illness, reducing visibility and making disposal sites dangerously unstable.

iii. The gases produced by burning cause different respiratory diseases. Aerosols and dust spread fungi and pathogens from uncollected and decomposing waste. Lack of plan in the management of solid waste led to epidemic of plague, malaria and the like. The problem of solid waste cause serious and long term pollution of air and water. Improvement in solid waste management leads to minimization of environmental impact.

iv. Landfills require a suitable lining system with efficient membrane embedded within so as to minimize the leachate infiltration. The proposed membrane is expected to satisfy the mentioned criteria and thus can be proposed to any landfill construction.

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