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Techno-Commercial Assessment of Concurrent Municipal Brown Field Reclamation Procedures: A Pivotal Case Study of Jawahar Nagar Dump Site

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Abstract: The quantity of municipal solid waste (MSW) generation is escalating at an alarming rate with every passing year alongside the modernization of our economy. Unfortunately, the majority of this waste remains uncollected or ends up in open dumping and followed by uncontrolled burning. Citing the deep-rooted consequences, open dumping should be abandoned, and scientific interventions should be aggressively exercised to reclaim the municipal brownfields. The present research undertook the judicial task of assessing the comparative feasibility of biomining and scientific capping as a technology selection for reclamation of about a decade-old 120 million tons of waste chunk laying at Jawahar Nagar dump yard. Primary dump samples were collected from various locations, considering depth as a variable. At the same time, leachate and groundwater samples were collected from Malkaram lake and preinstalled borewells receptively. Additionally, the ambient air quality and noise level also been ascertained within the buffer zone. The blended representative solid sample was segregated using a 70 mm mesh trommel into organic and inorganic fractions. The organic fraction was composted using a lab-scale aerobic static pile composting (ASPC) while the trommel reject was processed as refuse-derived fuel (RDF). Evidently, the compost lagged quality and depicted nutrient deficiency. In contrast, the burning of RDF produced siloxane gas significantly due to elevated silicon levels in the primary waste. Furthermore, due to the prolonged leaching tenure and seasonal dilution, the concentration of legacy leachate was relatively weaker. Borewell samples collected from a depth of 20 feet also portrayed minor contamination up to 500 meters horizontal radius. The issue of leachability can solely be resolved with the capping of the existing dump, and the end product quality derived from the biomining process is highly questionable. Thus, handling such large quantity capping is a befitting option over biomining for Jawahar Nagar dumpsite.

Keywords: municipal solid waste; legacy dump; bio-mining; scientific capping; reclamation.

1. Introduction

Presently, in India, due to rapid urbanization and industrialization, the generation of MSW has been increasing tremendously and is also expected to continue a similar trend in the future [1-4]. Annually, the comprehensive urban MSW generation in India is more than 62 million tons. Metro cities are the mammoth contributor of the entire chunk, and waste production had already reached an alarming figure of 50,000 tonnes/day. While the waste generation from the tier 2 cities is also rigorously escalating and presently contributes up to 20,000 tones/day [4]. A study conducted by the central pollution control board (CPCB) revealed MSW generation in India is increasing at a distressing rate of 5 % per annum with a sharp escalation in the quantities of domestic hazardous waste [4]. With major financial constraints, the inefficacy of collection, treatment, and disposal incurs further reasons to worry.

So far, India has miserably failed to set up wholesome source segregation and collection method. Presently, the country spends more than 60% of its annual waste management budget only on collection. Besides, only 20% or less of the collected materials are scientifically handled and treated. Citing the statistics, it is evident that most of the MSW is simply dumped on the low laying grounds located somewhere on the outskirts of the cities. The precipitation, infiltration, surface water runoff, bird menace, rodent interference etc., triggers the vulnerability of waste and leads to mal odor, ground and surface water contamination, human and environmental health deterioration [5]. Further, the perseverance of the inorganic and inert fractions leads to soil contamination, poses a fire threat, and also may incur carcinogenicity and acute toxicity among the animals [6].

There are numerous techniques for the reclamation and remediation of the dumpsites, including capping and closure, *in-situ* vitrification, sub-surface cut-off walls, and waste biomining [7,8]. Waste biomining is a stable way to eliminate the entire range of problems associated with open dumping and reclaim valuable land [9]. Several instances include reclamation of Mumbai Gorai dump yard by IL & FS Environment, 70 – 80 years old 12,00,000 tons of dump clearance by Nagar Nigam Indore within a short span of 3 years, and many more. But the process of biomining is highly sensitive and case-specific. The success of the process solely depends on factors such as characteristics of the waste, efficacy of the effective microorganism culture, acceptability of the processed end product at the local market, etc. [10-12]. Contrarily, though the scientific capping is not an end-to-end solution but still advisable when the quantity of waste is gigantic, land scarcity is prevalent, no nearby industries to consume the end products etc. Mehta *et al.* (2018) [13] have supported the above claim based on assessing location-specific MSW dump reclamation case studies. While in another Nagpur-based case study conducted by Ashootosh *et al.* (2020) [14] reported the superiority of the biomining process over simple land capping due to the favorability of the local conditions. Capping eliminates environmental interference and thereby reduces biosphere contamination and leachate generation. Further, it captivates rodent and vector breeding and thereby curtails the spreading of communicable diseases and improves aesthetics. But right consolidation through compaction and execution is of utmost necessity in the above case as non-compaction and faulty sloping will easily lead to heavy settlement and slope failure [15,16].

The present study has been pursued with the primary objective to run a techno-commercial assessment between scientific capping and biomining. At the same time, the secondary objective was to ascertain the level of contamination and propose mitigative measures.

2. Materials and Methods

The primary tasks performed were the sampling of the composite specimens from various locations and layers, design of lab-scale comparative experiment, and conduction of the thorough investigation and analysis of each of the samples. A detailed description of the work is delineated below.

2.1. Study area.

Spanning over 350 acres of a precious piece of land at the outskirts of Hyderabad city, Jawahar Nagar's dumping yard was brutally utilized by the Greater Hyderabad Municipal Corporation (GHMC) for open dumping for a prolonged tenure of 10 years. It housed nearly 12 lakh metric tons of heterogeneous solid and domestic hazardous waste and continues polluting until 2015 until the Ramky group was offered to cap the legacy dumping and scientifically handle the site. The present study has been facilitated at Hyderabad Municipal Solid Waste Limited, formerly known as Jawahar Nagar dump yard, to analyze and assess the feasibility of bio-mining as handling and management alternate to the existing practice of scientific capping. The epicenter of the processing and disposal facility is lying approximately on the cross-section of 17°31'24.45"N and 78°35'23.37"E. As per the contract, the comprehensive legacy dumping to be capped in three phases over about 150 acres of area, and Ramky has significantly entered phase two of the operation within five years by successfully capping more than half of the operation the legacy footprint.

2.2. Sampling methodology.

The waste pile was divided into three layers, namely, base, middle, and top. A uniform amount of sample was collected from the successive layers of all five different corners, covering the north, south, east, west, and center of the garbage pile. Sampling inspections were performed using a manual auger, besides large samples were collected using a JCB excavator. The top six-inch layer of the pile was removed to avoid contamination while collecting the samples, and 5-10 kg of sample was collected from each location. Further, intermediate and bottom layer samples were collected by digging a 500 mm diameter hole through the heap. A composite was prepared by a homogenized blending of all the fifteen grub samples. The blend was distributed into four equal quadrants, and the top and bottom quadrants were eliminated diagonally while the left-over quadrants were mixed thoroughly. This process was repeated until a sample of the required bulk of 20 kg is obtained.

Surface and subsurface water samples from borewells were collected in and around the facility. Piezometric monitoring borewells located near the landfills were utilized for the subsurface sample collection, while a rainwater pond turned leachate lake named Malkaram was determined as the primary source for leachate collection. Buffer samples were collected from Ambedkar Nagar, the nearby colony exiting at a distance of only 300 meters.

2.3. Lab-scale experimentation.

The representative sample was characterized for composition and further screened through a 70 mm mesh size trommel. The trommel permeate was considered as the organic fraction, while the reject was mostly inorganics and inert. The organics were subjected to ASPC. The quantity of the air required is arrived at using the method delineated below (Figure

1).

MSW Pile size: 2m x 0.5m x 0.5m

Volume of pile: 0.5 m^3

Average Density of MSW: 620 Kg/m^3

Weight of pile: 310 Kg

Nitrogen required for matured compost: 9300 mg/kg dry

: 9300 X 310 mg

: 2.88 x 10^6 mg

: 2.88 Kg

Total air required: 2.88 x 100/76 [as Nitrogen in air is 76% by weight]

: 3.79 Kg of dry air

: 3.79/1.225 m^3 [@ 15 deg C density of air 1.225 kg/m^3]

: 3.1 m^3

This air is to be supplied for 100 min/day for 0.5 m pile

Airflow rate required: 3.1 x 60/100 = 1.86 m^3/h (for the practical purpose, a flow rate of 2 m^3/h was maintained).

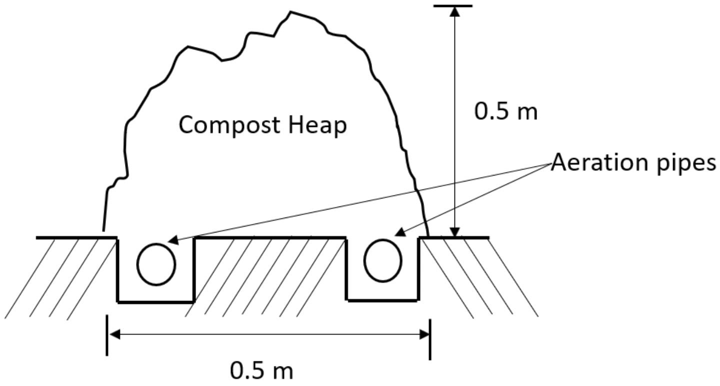


Figure 1. Cross-section of ASPC process.

The maturation period was considered as 28 days, and post-maturation, the stabilized material was further cured for 24 hours and screened using 12 mm and 4 mm trommel, respectively, to obtain the desired product quality and particle size.

The trommel reject was evenly spreader on the copper trays and dried in an oven at 105°C for 2 hours. The dried material was micronized to 50 mm or below using a scissor, and inert such as glass, sand, stone etc., were segregated manually [17].

Concurrently, a bench-scale capped landfill prototype was built using the below-mentioned procedure to evaluate the factors such as settlement and slope stability. A 30 mm thick low permeable soil was laid on the top of the waste, followed by a 60 mm layer of compacted clay liner (CCL). Each join between successive liner material was closely monitored. A 1.5 mm thick HDPE liner was placed on the top of the CCL. A 285 GSM geotextile membrane was placed as the above successive layer followed by a 15 mm thick drainage media layer. A further layer of geotextile membrane was placed on top of the drainage media to stabilize better, grip, and strengthen. The top vegetative soil layer of 45 mm thickness was laid off on top of the geotextile media, and St. Augustine grass was rooted [18,19].

2.4. Sample analysis.

pH, Electrical Conductivity (EC), and Turbidity of the samples were analyzed using pH, EC-TDS, and Nephelometer of Mettler Toledo. The pH meter was calibrated with the buffer solution of 4.0, 7.0 & 9.12 at a controlled temperature. EC-TDS meter was calibrated with 0.1 M KCL having 12.8 mS/cm of conductivity. Nephelometer was calibrated with Formazine solution of 10 & 100 NTU. Total Dissolved Solids (TDS), (mg/L) was performed using the gravimetric method at 180^0C in the oven.

Titrimetric parameters such as Total Alkalinity as $CaCO_3$ (mg/L), Total Hardness as $CaCO_3$ (mg/L), Chloride as Cl^- (mg/L), Calcium as Ca^{2+} (mg/L), Residual Free Chlorine (RFC), (mg/L) were analyzed using APHA (American Public Health Associations) method, 23rd Edition, 2017. Total Kjeldahl Nitrogen (mg/L) and Ammonical Nitrogen (mg/L) were performed through distillation followed by titration with H_2SO_4 as a titrant. Sulfide as S^{2-} was done with the Iodometric method after distillation. Each titrimetric parameter was analyzed in triplicate after standardizing the titrant with required reagents and cross-checked by keeping a standard.

Sodium as Na (mg/L) and Potassium as K (mg/L) were performed using Flame Photometer. The photometer was calibrated with different standards from 10 to 100 (mg/L) standard solutions. The leachate sample was diluted enough to get the value within the standard range and cross-checked with check standards at the same time.

Chemical Oxygen Demand (COD), (mg/L) was performed using the open reflux method for 2 hours at 150°C in COD Digestor. Biochemical Oxygen Demand (BOD), (mg/L) was performed using the alkali iodide azide method for 3 days. The samples were kept in a BOD incubator at 27^0C for 3 days. It was kept in duplicate to have a check on quality control.

Sulfate was analyzed using the gravimetric method instead of turbidimetric or through UV-Visible spectrophotometer as its concentration was found to be more than 40 mg/L. Nitrate as NO_3^- was analyzed after filtration at 220-275 nm, while Hexavalent Chromium as Cr^{6+} was analyzed at 540 nm in the UV-Vis. Parameters like Cyanide as CN^-, Fluoride as F^-, and Phenolic Compounds were gone through a distillation process followed by UV-Vis. The distillation process ensures the removal of interferences presents either positive or negative. For the parameters like Total Iron or Ferric Iron, the samples were digested properly with the required reagents on the hot plate before analyzing in UV-Vis.

For the metal analysis, the water samples were digested at a temperature of 100°C using aqua regia as a medium. The samples were digested to one-fourth of the volume on a hot plate. The recommended wavelengths as per APHA 3120 B were selected for each of the metals. The standard graph was plotted for each of the metals before analysis and crossed checked with the check standard simultaneously.

Parameters such as bulk density and particle size were performed through the certified beaker and sieve. The percentage of moisture content was estimated using the oven by keeping the compost sample for 2 hours at 105^0C. C/N ratio was estimated through a CHNS analyzer keeping sulfanilamide as a check standard. The analysis was performed by extracting the desired component in the desired solution prescribed in the method followed by converting the same from mg/L to mg/Kg.

3. Results and Discussion

An exhaustive bench study has been pursued, and real-time samples were collected and analyzed for all possible parameters to determine the pros and cons attributed to both processes. The investigation begins by collecting the samples and concluded with impact assessment studies inclusive of the buffer zone. Both solid, liquid, and gaseous samples were precisely investigated to opt for the best solution. A detailed finding of the investigation is summarized below.

The solid representative sample was primarily characterized through a manual separation process, and the results are portrayed in Figure 2.

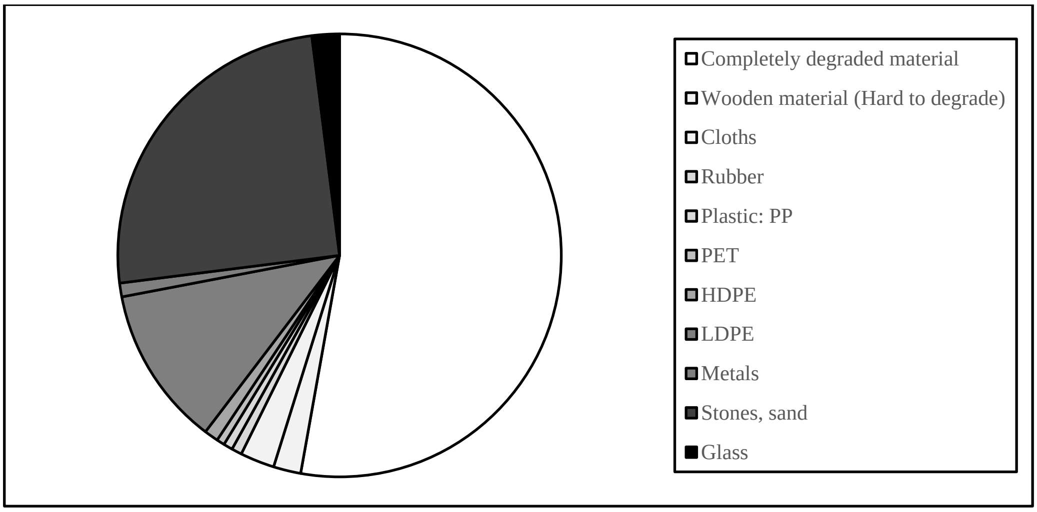


Figure 2. Composition of the legacy dump.

3.1. Compost characterization.

ASPC of the organic fraction has resulted in a recovery of 46.7% of the initial load. While 53.3% of the influent mass was inert and barely degradable fraction contributes to reject, the rest, 4.1%, is miscellaneous process loss. The processed compost was extensively analyzed, including for metal contamination, and the same is tabulated in Table 1.

Table 1. Characteristics of compost sourced from the legacy dump.

No.	Parameter	Unit	Result	Standard[1]
1.	Physical State	-	Solid	-
2.	Color	--	Dark Brown	Dark Brown to Black
3	Particle Size	%	94.2	Min 90% Dry Weight Passing through 4mm sieve
4.	Odor	-	Absence of foul odor	Absence of foul odor
5.	pH (10% Solution)	-	7.36	6.5-7.5
6.	EC (10% Solution)	µmho/cm	3388	4.0 dsm-1
7.	Bulk Density	gm/cc	0.90	<1.0
8.	Moisture Content	%	21.9	15-25
9.	C/N Ratio	-	39.11	<20:1
10.	Organic Carbon (OC)	%	10.2	>12.0
11.	Total Nitrogen (TN)	%	0.6	>0.8
12.	Potassium as K_2O	%	0.31	>0.4
13.	Phosphate as P_2O_5	%	0.28	>0.4
14.	Total Nitrogen as N, Phosphate as P_2O_5, and Potash as K_2O (NPK)	-	0.82	<1.2
15.	Arsenic as As	mg/kg	3.8	10.0
16.	Lead as Pb	mg/kg	31.8	100
17.	Cadmium as Cd	mg/kg	3.24	5.0
18.	Chromium as Cr	mg/kg	20.6	50.0
19.	Nickel as Ni	mg/kg	<0.2	50.0

No.	Parameter	Unit	Result	Standard[1]
20.	Zinc as Zn	mg/kg	244	1000
21.	Copper as Cu	mg/kg	206	300
22.	Mercury as Hg	mg/kg	<0.01	0.15

[1]Organic Fertilizer as per FCO (Amended Feb 2019)

The value of C/N ratio, OC, TN, K_2O, P_2O_5, and NPK evidently portrays the shortcoming in terms of nutrient availability. Though it is highly enriched in organic carbon, the same can be effectively utilized as a soil preconditioner. Ayilara *et al.* (2020) [20] also reported a similar finding, where the city compost sourced from MSW lagged major plant nutrients.

3.2. RDF characterization.

Processed trommel rejects constitute cloth, rexine, leather, jute, paper, plastics, coir, and other inert contributed to RDF. The fraction of inert was as high as 37.2% of the overall RDF mass, and it mostly constituted glass and sand. The combined weight of sand and glass fragments contributed 73.5% of the total inert, while the rest was stone and small brickbats. The higher level of silicon associated with the presence of glass and sand yielded siloxane and triggered the possibility of kiln corrosion. A detailed RDF analysis report is enclosed in Table 2.

Table 2. Characteristics of RDF sourced from the legacy dump.

No.	Parameter	Unit	Method	Result	Standard- RDF-Grade-I[1]
1.	Moisture Content	%	ASTM E790-15 Standard	16.82	< 20%
2.	Net Calorific Value (NCV)	kcal/kg	ASTM E955-88(2009)e1 Standard	1858	>3000 KCal/kg net
3.	Ash	%	ASTM D5630-13	22	<15
4.	Chlorine	%	ASTM E776-16 Standard	2.4	< 1.0 %
5.	Sulfur	%	ASTM E775-15 Standard	3.6	<2%

[1] Specifications based on American Society for Testing and Materials

The values explicitly portray that the quality of RDF is moderately lower, and higher salts concentration is extremely prevalent. With relatively lower NCV and high salt concentration, the above specimen will pose a corrosion threat to the kiln and be neglected as kiln feed or utilized after dilution with Grade III RDF quality. Further, such high ash generation will also induct high transportation and landfill charges.

3.3. Leachate characterization.

The Malkaram leachate lake results from prolonged, slow, and steady mixing of the legacy leachate through the existing fissure cracks in the sheath rock bottom profile. Apparently, the concentration of leachate is significantly lower due to the dilution. Samples were analyzed in triplicates, and the mean value is tabulated here in Table 3.

Table 3. Characteristics of Malkaram leachate.

No.	Parameters	Units	Method	Result
1	pH @ 25^0C	-	APHA 4500 H^+ B	7.89
2	Electrical Conductivity	µMhos/cm	APHA 2510 B	53988
3	Total Dissolved Solids (TDS)	mg/L	APHA 2540 C	31554

No.	Parameters	Units	Method	Result
4	Chlorides as Cl^-	mg/L	APHA 4500 Cl-C	10826
5	Sulphates as $SO4^{-2}$	mg/L	APHA 4500 SO4-2 D	510
6	Kjehldal Nitrogen	mg/L	APHA 4500 N (org) B	854
7	Ammonical Nitrogen	mg/L	APHA 4500 NH3 B, C	820
8	Nitrates as NO_3-N	mg/L	APHA 4500 $NO3^-$ B	130
9	Alkalinity as $CaCO_3$	mg/L	APHA 2320 B	5498
10	Calcium as Ca	mg/L	APHA 3500 Ca B	456
11	Magnesium as Mg	mg/L	APHA 3500 Mg B	140
12	Sodium as Na	mg/L	APHA 3500 Na B	6792
13	Potassium as K	mg/L	APHA 3500 K B	5254
14	Fluoride as F^-	mg/L	APHA 4500 F- D	3.56
15	Chemical Oxygen Demand	mg/L	APHA 5220 B	14556
16	Biochemical Oxygen Demand (3 day at 27ºC)	mg/L	IS 3025 (P-44)	4388
17	Oil & Grease	mg/L	APHA 5743 B	<10
18	Lead as Pb	mg/L	APHA 3120 B	0.21
19	Cadmium as Cd	mg/L	APHA 3120 B	<0.003
20	Total Chromium as Cr	mg/L	APHA 3120 B	0.24
21	Chromium as Cr+6	mg/L	APHA 3500 Cr B	<0.05
22	Nickel as Ni	mg/L	APHA 3120 B	0.51
23	Zinc as Zn	mg/L	APHA 3120 B	0.62
24	Manganese as Mn	mg/L	APHA 3120 B	0.28
25	Copper as Cu	mg/L	APHA 3120 B	<0.1
26	Mercury as Hg	µg/L	APHA 3120 B	<0.1
27	Arsenic as As	mg/L	APHA 3120 B	<0.2
28	Cyanide as CN-	mg/L	APHA 4500 CN- E	<0.1
29	Phenolic compounds As Phenols	mg/L	APHA 5530 D	<0.001
30	Iron as Fe	mg/L	APHA 3500 Fe B	25.4
31	Iron as Fe^{+3}	mg/L	APHA 3500 Fe B	<0.2
32	Sulphide as S^{-2}	mg/L	APHA 4500 S2 F	1.92

The metal concertation and rest of the parameter values are well within the secondary treatment influent range, except for TDS. Thus, a modular aerobic biological treatment unit such as moving bed biofilm bioreactor (MBBR) or membrane bioreactor (MBR) would be a well-suited pick. However, a reverse osmosis (RO) system needs to be installed to eliminate the high TDS content. The permeate of RO can be reused back into the system, whereas the reject can be converted into dried powder through forced evaporation mechanisms. The higher concentration of salts in RDF collaterally justifies the elevated TDS level in leachate. In a leachate impact assessment study performed by El-Salam and Abu-Zuid (2015) [21] the reported BOD/COD ratio of 0.69 is greater than double the value of 0.301 reported in Table 3. Though the difference in both the values is quite high, it is relatable and justifiable by the huge age difference of the source waste. The primarily characterized data is fresh leachate generated from regular MSW, while the latter is from a decade-old waste that barely has any unstabilized organic content.

3.4. Groundwater contamination.

The obvious reason for downward leachate infiltration and osmotic movement facilitates groundwater contamination. Both surface and subsurface water samples were collected within the dump yard and the buffer zone and analyzed using the standard methods. The results are portrayed in Table 4.

Table 4. Characteristics of in and around surface and subsurface water.

No.	Parameters	Units	Method	Water samples		Standard[1]
				Borewell	Surface water sample	
1	pH	--	APHA 4500 H+ B	8.24	7.82	6.5- 8.5
2	Total Dissolved Solids	mg/L	APHA 2540 C	3956	2054	500
3	Total Alkalinity as $CaCo_3$	mg/L	APHA 2320 B	322	328	
4	Total hardness as $CaCo_3$	mg/L	APHA 2340C	2398	1144	300
5	Calcium as Ca^{+2}	mg/L	APHA 3500 Ca	525	246	
6	Residual free chlorine as Cl^-	mg/L	APHA 4500 Cl	0	0	
7	Nitrates as NO_3-N	mg/L	APHA 4500 NO3-B	31.2	62.3	45
8	Fluoride as F^-	mg/L	APHA 4500 F	1.27	0.9	
9	Chlorides as Cl^-	mg/L	APHA 4500 Cl-B	1838	684	250
10	Sulphate as SO_4	mg/L	APHA 4500 SO4	138	152	200
11	Phenolic Compounds	mg/L	APHA 5530 D	<0.1	<0.001	0.002
12	Cyanide as CN	mg/L	APHA 4500 CN- E	<0.2	<0.1	0.05
13	Arsenic as As	mg/L	APHA 3120 B	<0.05	<0.05	0.01
14	Cadmium as Cd	mg/L	APHA 3120 B	<0.003	<0.003	0.01
15	Copper as Cu	mg/L	APHA 3120 B	0.24	<0.05	0.05
16	Lead as Pb	mg/L	APHA 3120 B	0.28	<0.01	0.05
17	Zinc as Zn	mg/L	APHA 3120 B	<0.5	<0.5	5
18	Nickel	mg/L	APHA 3120 B	<0.02	<0.02	0.02
19	Manganese as Mn	mg/L	APHA 3120 B	0.26	<0.1	
20	Iron as Fe	mg/L	APHA 3500 Fe B	<0.2	<0.2	0.3
21	Chromium	mg/L	APHA 3120 B	<0.05	<0.05	0.05
22	Chromium as Cr^{+6}	mg/L	SW-846 7196 B	<0.05	<0.05	
23	Boron	mg/L	APHA 3120 B	<0.5	<0.1	
24	Oil & Grease	mg/L	APHA 5520 B	<1.0	<1	
25	Odour		--			
26	Dissolved Oxygen	mg/L	APHA 4500 O	3.5	5.1	>4.0
27	Turbidity	NTU	APHA 2130 B		25	
28	Mercury as Hg	mg/L	APHA 3120 B	<0.1	<0.1	0.001

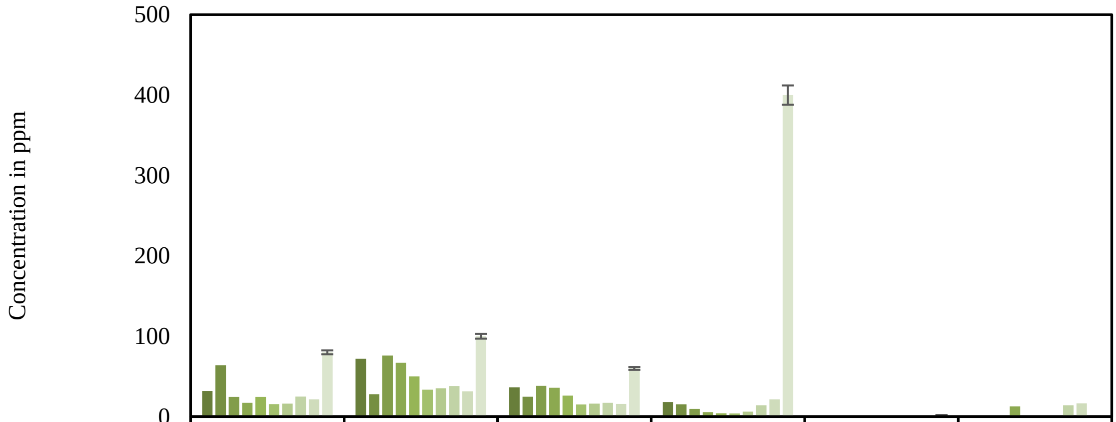
[1] As per Bureau of Indian Standards (BIS) 10500

The slightly alkaline pH of the borewell sample is an indication of the ongoing anaerobic process. The dissolved oxygen value of 3.5 mg/L further validates the correlation. Higher TDS and hardness values are self-indicative of elevated salt concentration in source waste. Eventually, the same interfered with the RDF quality. Positively in the case of all the parameters, a successive decrement in pollution concentration has been spotted from the dump ground towards the buffer zone. In a similar study conducted by Singh *et al.* (2016) [22] at Varanasi, Uttar Pradesh, the reported concentration of the parameters is significantly higher than reported in Table 4. The basic reason behind variation is the dissimilarities of the local soil profile. The sandy and clay loam soil profile of Varanasi allows a greater rate of percolation and infiltration.

In comparison, the bottom sheath rock profile at Jawahar Nagar permits only a minute to little percolation rate. The difference in percolation rate is directly correlated to the concentration levels in this case. Contrarily, Kurakalva *et al.* (2016) [23] reported much-elevated pollutant concertation in ground and surface water for a study conducted at the same site in 2016. The higher concentration is relatable to the fact of the non-closure of the open dump back then. Capping activity had at Jawahar Nagar gained its pace from 2018 onwards, and capping for the primary section of 70 acres was concluded only during mid-2019. Due to the decrement in runoff and percolation, both surface and subsurface water quality have improved drastically.

3.5. Impact assessment.

The odor and groundwater contamination are two of the primary issues that triggered a massive public agitation initially. The root causes of both the issues are identified as rainwater percolation and anaerobic digestion, respectively. Eventually, the completion of the capping process would resolve both problems effectively. Other non-tangential impacts include nausea; headache; irritation of the eye, nasal cavity, and throat; diarrhoeal diseases; vector-borne disease, cattle toxicity, etc. Scientific capping can easily cater as a wholesome solution for all [17]. Yu *et al.* (2018) [24] had performed an extensive study to comprehend the relativity of respiratory sickness and MSW-borne air pollution. The study made a couple of dreadful revelations such as gases released due to the anaerobic digestion of MSW such as methane, hydrogen sulfide, and ammonia incur detrimental impact on Lysozyme and secretory immunoglobulin A (SIgA). While SO_2 was reported as the lung capacity and functionality reducer. Further, the same research group executed a gender-specific study that revealed that air pollution impacts more severely on male children than females and retards immune functions.



	Sulfur Dioxide (SO2)	Particulate matter (PM 10)	Particulate matter (PM 2.5)	Ammonia(NH3)	Carbon Monoxide	Methane
2020	32	72	36,5	18,2	0,9	1,2
2019	64	28	24,7	15,5	0,7	0,5
2018	24,6	76	38,4	9,6	0,8	1
2017	17,2	67	36	5,6	0,8	12,8
2016	24,5	50	26,2	4,2	0,3	0,4
2015	15,52	33,6	15,3	4,05	0,1	0,2
2014	16,25	35,24	16,12	6,32	0,6	0,8
2013	24,9	38,2	17,3	14,2	0,6	14,2
2012	21,6	31,5	15,9	21,6	0,6	16,7
STANDARDS	80	100	60	400	2	25%

Air quality parameters

2020 2019 2018 2017 2016 2015 2014 2013 2012 STANDARDS

Figure 3. Consolidated report of ambient air quality between 2012 to 2020.

Presently, the area of 351 acres has been developed as Asia's one of the largest state-of-the-art municipal solid waste processing and disposal facilities by Ramky Enviro Engineers Limited. This ensured zero dumping and no further environmental interventions. As legal compliance, the facility monitors groundwater quality and ambient air quality in and around the facility monthly to ensure biosafety. The variation in concentration of various monitoring parameters between 2012 to 2020 is summarized in Figure 3.

The concentration of each of the parameters is showcased in ppm, and a standard equipment error was settled at 3% for respirable dust sampler and multi-gas analyzer [25]. Although all parameter values have gradually increased except for methane, the facility still managed to maintain them well under the regulatory limits. The decrement in methane concentration is directly correlated to the practice of aerobic composting and aeration-based secondary treatment that prevented the formation of the anaerobic atmosphere and henceforth methane generation. While for the rest of the parameters, the increment in values is quite substantial and predictable due to the sudden escalation in MSW generation in the past decade in correlation with Gross domestic product (GDP) enhancement. The observed and interpreted impacts due to the elevated pollutant level align with the georeferenced findings reported by Deshmukh and Aher (2016) [26] based on a study conducted at Sangamner, Maharashtra.

4. Conclusions

The study critically analyzed and investigated every techno-environmental and socio-economic aspect correlated to open dumping. The bench-scale experimentation revealed that the single-liner scientific capping efficiency is fair enough to eliminate any further rainwater infiltration. However, it has no control over the generation of leachate due to the inherent moisture. The internal moisture-related issue was anyhow compensated with pertinent compaction before disposal of the waste. Contrarily, both the products derived through the biomining process, namely, compost and RDF, lagged quality due to scantier nutrient content and higher salt and silicon content, respectively. Besides, impact assessment studies concede that the pollutant concentration in groundwater in and around the plant has drastically diminished post-July 2019 due to the partial completion of waste capping. It also abetted lowering the dust and odor issues relatively in the surrounding.

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Conflicts of Interest

The authors declare no conflict of interest.

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