Municipal Solid Waste Management; Air Pollution and its' Impact

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Abstract – *The emission of pollutants during processing of solid waste is of great concern due to its hazardous effects. An assessment of air quality of the solid waste management sites were made and transfer stations during February to June 2021 and October to December 2021. Parameters such as particulate matter ($PM_{2.5}$), particulate matter (PM_{10}) were measured along with other parameters. An assessment of air quality showed their levels of their mean value ranged between 50.7 and 89.6 µg/m3 at sources and 69.54 and 95.79 µg/m3 at downwind. GHG showed lower levels than the proposed limit value, which could not cause any health issues, while PM2.5 was 4-7 times higher than the standards established. Higher pollutant concentration was recorded in the month of February to June than the month of October to December. Thus, it is estimated that the ambient air of the sites is not safe for people living there. Hence, it is necessary to use safe practices for MSWM and its emission control.*

Key Words: $PM_{2.5}$, PM_{10}, SWM, CPHEEO, Bio methanation, Incineration, GHG.

1.1 NTRODUCTION

Solid Waste Management is one of the most essential services for maintaining the quality of life in the urban areas and for ensuring better standards of health and sanitation [1]. In India, this service falls short of the desired level, as the systems adopted are outdated and inefficient. Institutional weakness, shortage of human and financial resources, improper choice of technology, inadequate coverage and lack of short and long term planning are responsible for the inadequacy of service[2].

It is a major challenge in cities with high population density in India as the per capita generation of Muncipal solid waste has also increased tremendously[3]. As more land is needed for the ultimate disposal of these solid wastes, issues related to disposal have become highly challenging. The waste Management and Handling Rules in India were introduced by the Ministry of Environment and Forests[4,5,6].

Ill management of solid waste leads to problems that impair human and animal health. Impact of waste depends on composition of waste and practices involving illegal disposal. Solid waste creates several noxious gases such as suspended Sulphur Dioxide (SO2), oxides of Nitrogen (NOX), Carbon Monoxide (CO), Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM). Pollution due to waste dumping affects health through both short and long-term effects. Examples of short-term and long-term include asthma and respiratory infection, respiratory chronic respiratory and cardiovascular diseases, cancer respectively. According to international solid waste association (ISWA), 2.6 million tons per day of municipal solid waste is produced globally, and the amount may reach up to 4.5 million tons per day by 2050 [7,8,9,10].

The management of solid waste is in association with the control of its production, collection and storage and finally is transferred to disposal sites by following the best principles of health, finances, aesthetics and ecological aspects[11,12]

2. MATERIALS AND METHODS

2.1 Description of study area

Kirandul is a city and a municipality in the Dantewada district in the State Chhattisgarh, India. It is a twin township consisting of Kirandul and Bade Bacheli of Bailadila region. Bailadila means "hump of the ox", and the mountain range here has peaks that look like the humps of an ox.

Present average generation of waste in the study area is about 320 g/capita/ day as per the actual survey. The city Kirandul has the deficiencies in managing MSW in varying degrees and there is a need to set up a new solid waste management technique to improve the present SWM practices prevailing in the city to raise the standards of health, sanitation and urban environment. Government of India has launched a "Swachh Bharat Abhiyan (SBA)" or "Clean India Mission" covering 4041 statutory towns to clean the streets, roads and infrastructure of the country.

Population projection of Bailadila region, Chhattisgarh is shown in Table-1

Table -1: Decadal Population Data

Population Census Date	Population
1-March-1991	19,623
1-March-2001	19,059
1-March-2011	18,887

(Source: Office of the Registrar General and Census Commissioner Delimitation Commission of India)

Table -2: Projected population

Year	2021	2031	2041
Population	18583	18283	17991

2.2 Present SWM Scenario of Bailadila Region, CG

The region does not have any door to door collection and source segregation system at present. Wastes are transferred by individual households into community bins without segregation. The mixed waste (wet and dry) from the community bins is emptied and loaded into transportation vehicles (tractors)

Fig- 1: Secondary Collection bin at Railway colony, Kirandul

Presently, waste processing is not carried out Bailadila area. Entire mixed waste is collected from individual households

or from the secondary collection points and transported to the low-lying area for dumping.

There are no environmentally suitable and demarcated dumping yards in the city, but most of the municipal solid waste is dumped at Old MV Siding area and near Railway Colony at Bailadila region that is considered as the only dump yard.

Waste Generation Projection- The waste generation estimate is carried out on the following assumptions:

- Increment in waste generation rate is 0% per annum
- Floating population is considered as 0%
- Waste generation for Bailadila area for year 2021 is taken as 0.320kg/capita/day

Fig- 2: Waste dumping at Railway colony

- is same as that of 2021 as the population is decreasing

Total projected population is 18,887 for the year 2041 (Same as that of 2011) as the population is decreasing.

Table -3: Waste Generation Estimate for Bailadila area

Sampling Month	Recyclable waste (% by weight)	Incinerable waste (% by weight)	Compostable waste (% by weight)	Land filling waste or inert waste (% by weight)
Feb 2021	21.91	4.15	52.16	21.77
June 2021	25.39	9.99	43.65	20.97
Average of the data collected during Feb and June 2021	23.65	7.07	47.90	21.37
Waste Generation (Tons / Annum)	521.38	155.86	1056.11	471.1
Waste Generation (Tons/Day)	1.42	0.427	2.89	1.29

Waste Composition:

The quantity as well as its composition (biodegradable, recyclables etc.) are required to arrive at proper technology (ies) for waste processing, viz. Compositing, Biomethanation (BM), Waste to Energy (WtE), Landfilling, Recycling etc. The waste composition estimate has been calculated based on field studies, laboratory experiments and as per CPHEEO guidelines.

Solid Waste Qualitative and Quantitative Assessment

The qualitative and quantitative assessment for solid waste was carried out for Bailadila area in February - June 2021. Details of the sampling and analysis are given in following sections.

Waste Sample Collection and Analysis

The quantitative and qualitative assessment of waste in the city, especially its physical and chemical properties are essential for determining the future technological options for its treatment and disposal. The findings from this study will feed into the process and facilitate taking future decisions, especially in terms of selection of the technology.

As a methodology, in the absence of any existing information on MSW of Bailadila region, profiling has been taken up to understand the solid waste characteristics, collection system, treatment processes, disposal methods and other management issues. Total 35 solid waste samples each in February- June 2021 were collected from different locations like commercial area, markets, residential area, collection bins, and existing dumping sites.

4. RESULT AND DISCUSSION

4.1 Results of the Field Survey and the Laboratory Studies on the Solid Waste Samples Collected During Field Survey

Quantity of Waste Generation

The quantification of waste generation was done based on actual household survey during the field visit in June 2021 by IIT (ISM) representatives, Census Records and Average waste Generation rates as per Manual on Solid Waste Management by Central Public Health & Environment Engineering Organization (CPHEEO), Ministry of Urban Development, Govt. of India and the data collected on the total wastes collected by collection vehicles during the field visit.

Waste Characterization

The collected samples of Municipal Solid Wastes (MSW) were broadly categorized into following four categories: (i)

biodegradable waste that include food and kitchen waste, green waste (vegetables, flowers, leaves, fruits), papers (that can be recycled); (ii) recyclable materials that include papers, glass, bottles, cans, metals, certain plastics, etc.; (iii) inert wastes that include construction and demolition waste, dirt, rocks, debris etc. and (iv) non- biodegradable waste. The detail analysis (using standard methods) of the collected solid waste samples are presented in Table 4 (weight and type of wastes present in each sample) and Table 5 (presence of biodegradable and non-biodegradable waste materials in percentage).

Table - 4: Composition of the collected municipal solid waste samples from the site

S.N	**Biodegradable**	% by weight
1	Litter	5.59
2	Sewage waste	16.69
3	Textile	4.87
4	Card paper	4.48
5	Coconut Core	5.12
6	Sugar cane	4.02
7	Paper	3.23
8	Kitchen waste	17.35
	Total	61.35%
	Non biodegradable	
1.	Plastic	4.75
2.	Mix waste	5.60
3.	Glass	6.06
4.	Construction waste	5.79
5.	Polythene	6.87
6.	Ash	9.58
	Total	38.65%

Table - 5: Percentage of biodegradable and non-biodegradable wastes in the collected samples

S.N	**Sample No.**	**Type of waste**	**Weight (in gm)**	**Weight in %**
1	S1	Litter	299	5.59
2	S2	Sewage waste	898	16.69
3	S 3	Textile	260	4.87
4	S 4	Construction Waste	309	5.79
5	S 5	Polythene	367	6.87
6	S 6	Ash	512	9.58
7	S 7	Glass	324	6.06
8	S 8	Plastic	254	4.75
9	S 9	Card paper	239	4.48
10	S 10	Coconut Core	273	5.12
11	S 11	Sugar cane	215	4.02
12	S 12	Paper	172	3.23
13	S13	Kitchen waste	927	17.35
14	S14	Mix waste	300	5.60
15	Total		5349	

Moisture Content

The moisture content of solid wastes usually is expressed as below:

$$M = \frac{(w - d) * 100}{w}$$

Where,

M - moisture content, wet basis (%)

w – initial (wet) weight of sample

d – final (dry) weight of sample

The results of the moisture content analysis for all collected solid waste samples are presented in Table 6. The moisture content test was done using standard method and calculation was done on the basis of the above equation.

Energy Content and Density of Solid Waste Components

The energy content of solid waste components can be determined using (i) a full scale boiler as a calorimeter (ii) a laboratory bomb calorimeter and (iii) calculation, if the elemental composition is known. Density is defined as the weight of a material per unit volume (kg/m3). The density data are needed to assess the total mass and volume of the waste that must be managed. The density and calorific value (energy content) of the collected samples of municipal solid waste are presented in Table 7.

Table - 6: Moisture contents of the collected MSW samples collected from Bailadila

S. N	Sample Number	Moisture content (%)	Material
Sector A			
1	S1 D to D	40%	Mixed kitchens waste
2	S 2 D to D	80%	Vegetable peels
3	S 3 D to D	85%	Bread
4	S 4	6.67%	Litter
5	S 5	2.43%	Paper & board
Sector B			
1	S1 D to D	66%	Mixed waste kitchen waste
2	S 2 D to D	6%	Mixed
3	S 3 D to D	80%	Kitchen waste
4	S 4	25%	Mixed waste
5	S 5	30%	Sewage

Solid waste contains organic as well as inorganic matters. The latent energy present in its organic fraction can be recovered for beneficial utilization through adoption of suitable waste processing and treatment technologies. The recovery of energy from wastes offers a few additional benefits such as (i) the total quantity of waste gets reduced by nearly 60% to 90% depending upon the waste composition and the adopted technology, (ii) demand for land, which is already scarce in cities, for landfilling is reduced, (iii) the cost of transportation of waste to far away landfill sites also gets reduced proportionately, and (iv) net reduction in environmental pollution. The important physical parameters for energy recovery that to be considered include size of the constituents, density, and moisture content. Smaller size of the constituents aids in faster decomposition of the waste. The important chemical parameters to be considered for determining the energy recovery potential and the suitability of waste treatment through bio-chemical or thermo-chemical conversion

technologies include (i) volatile solids, (ii) fixed carbon content, (iii) inertness, (iv) calorific value, (v) C/N ratio (Carbon/Nitrogen ratio), and (vi) toxicity.

Table- 7: Calorific value and density of MSW collected from Bailadila Region

S.N	Sample number	Type of MSW	Calorific value	Density kg/m3
Sector A				
1	Sample 1 D to D	Mixed kitchens waste	4353.7	740
2	Sample 2 D to D	Vegetable peels	3600.31	
3	Sample 3 D to D	Bread	4353.7	740
4	Sample 4 dustbin	Litter	3768.64	460
5	Sample 5 dustbin	Paper board	4122.4	-
Sector B				
1	Sample1 D to D	Mixed waste kitchen waste	4353.7	740
2	Sample 2 D to D	Mixed waste	4476.91	555
3	Sample 3 D to D	Kitchen waste (vegetable peels)	3600.31	-
4	Sample 4 Dustbin	Mixed waste	4476.91	555
5	Sample 5 Dustbin	Sewage	2080	-

Proximate Analysis

Proximate analysis of the solid waste samples includes the following tests: (i) loss of moisture (loss of moisture when heated to 105 °C for 1 hr), (ii) volatile matter (additional loss of weight on ignition at 950 °C in a covered crucible), (iii) fixed carbon (combustible residue left after volatile matter is removed), and (iv) ash (weight of residue after combustion in an open crucible).

The above tests were carried out using standard methods in laboratory (using Oven and Muffle Furnace) and presented in Table 8.

Table- 8: Proximate analysis of the collected municipal solid waste samples from Kirandul

S.N	Sample number	VCM (%)	Ash %	Fixed carbon % (in 1 gm sample)
Sector A				
1	Sample 1 D to D	80.81	12.18	7.01
2	Sample 2 D to D	35	20	45
3	Sample 3 D to D	75.5	2	22.5
4	Sample 4 dustbin	73.52	20.565	5.92
5	Sample 5 dustbin	79.3	13.80	6.90
Sector B				
1	Sample1 D to D	80.81	12.18	7.01
2	Sample 2 D to D	84.05	10.5	5.8
3	Sample 3 D to D	47	19	34
4	Sample 4 Dustbin	66	7.6	26.4
5	Sample 5 Dustbin	30	50	20

Ultimate Analysis of Solid Waste Components

The Ultimate Analysis of Solid Waste Components typically involves the determination of the percentage of C (Carbon), H (Hydrogen), O (Oxygen), N (Nitrogen), S (Sulfur) and ash. The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in MSW. They are also used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes. The results of the Ultimate Analysis were obtained using a State of the Art equipment, CHONS analyser in the Department of Environmental Science and Engineering, IIT (ISM) Dhanbad for the collected solid waste samples and presented in Table 9.

Table- 9: Ultimate analysis of the collected municipal solid wastes

S.N	Sample number	C%	H %	S%
Sector A				
1	Sample 1 D to D	40.09	10.34	0.13
2	Sample 2 D to D	39.03	5.51	0.20
3	Sample 3 D to D	40.09	10.34	0.13
4	Sample 4 dustbin	40.71	5.00	0.10
5	Sample 5 dustbin	29.61	3.78	0.08
Sector B				
1	Sample1 D to D	40.09	10.34	0.13
2	Sample 2 D to D	38.50	4.85	0.18
3	Sample 3 D to D	39.03	5.51	0.20
4	Sample 4 Dustbin			
5	Sample 5 Dustbin	43.07	5.30	0.21

Categorization of the solid waste samples based on the laboratory test results The analysis results of the collected samples were used to sub-categorize the total municipal solid wastes into recyclable waste, incinerable waste, compostable waste, and land filling waste. Results are presented in Table 10.

Table -10: Waste categorization on the basis of recyclable, incineration, composting and land filling (February to June)

Recyclable waste in total MSW(%) in weight	Incinerable waste in total MSW (%) in weight	Compostable waste in Total MSW (% by weight)	Land filling waste in total MSW % in weight
Paper -3.23	Textiles - 4.87	Kitchen waste-17.35	Construction waste- 5.79
Plastics - 4.75	Coconut Coir- 5.12	Litter-5.59	Ash-9.58
Polythenes -6.87	-	Sewage waste- 16.69	Mixed waste- 5.60
Card paper -4.48	-	Sugar cane - 4.02	
Glass-6.06	-		
Total-25.39%	9.99%	43.65%	20.97%

4.2 Results of the Field Survey and the Laboratory Studies on the Solid Waste Samples Collected During Field Survey (October- Januray)

Waste Characterization

The detail analysis (using standard methods) of the collected solid waste samples are presented in Table 11 (weight and type of wastes present in each sample), Table 12 (presence of biodegradable and non-biodegradable waste materials), Table 13 (percentage composition of biodegradable and non-biodegradable wastes), and Table 14 (percentage composition of each type of solid wastes).

Table -11: Composition of the collected municipal solid waste samples from the site

S.N	Sample Number	Weight (gm)	Type of waste
Sector A			
1	Door to Door sample 1	256	Mixed kitchens waste
2	Door to Door sample 2	186	Vegetable peels
3	Door to Door sample 3	284	Bread
4	Dustbin sample 1	295	Litter
5	Dustbin sample 2	220	Paper & cardboard
Sector B			
1	Door to Door sample 1	200	Vegetable peels
2	Door to Door sample 2	201	Mixed waste (paper)
3	Door to Door sample 3	387	Kitchen (vegetable peels)
4	Dustbin sample 4	439	Mixed waste
5	Dustbin sample 5	397	Sewage
	Total waste weight	6974	

Table -12: Classification of municipal solid wastes samples based on degradability

S.N	Sample number	Biodegradable waste	Non-biodegradable waste
Sector A			
1	Sample 1 D to D	√	
2	Sample 2 D to D	√	
3	Sample 3 D to D	√	
4	Sample 4 dustbin	√	
5	Sample 5 dustbin	√	
Sector B			
1	Sample1 D to D	√	
2	Sample 2 D to D		√
3	Sample 3 D to D	√	
4	Sample 4 Dustbin		√
5	Sample 5 Dustbin	√	

Table-13: Percentage of biodegradable and non-biodegradable wastes in the collected samples

S.N	Biodegradable waste	Weight in %
1	Litter	5.75
2	Sewage	21.04
3	Clothes	2.69
4	Sugar cane	1.90
5	Paper & cardboard	7.52
6	Coconut core	1.46
7	Kitchen waste	23.47
	Total	63.83
	Non-biodegradable waste	
8	Construction waste	10.80
9	Polythene	2.92
10	Plastic	9.66
11	Ash	4.73
12	Glass	1.82
13	Mixed waste	6.24
	Total	36.17

Table -14: Composition of total waste sample in percentage

S.N	Material	Weight in gm	Percentage of total waste
1	Litter	401	5.75 %
2	Sewage waste	1468	21.04 %
3	Cloths	188	2.69%
4	Construction waste	703	10.80 %
5	Polythene	203	2.91 %
6	Ash	330	4.73 %
7	Glass	127	1.82 %
8	Plastic	669	9.66 %
9	Kitchen waste	1637	23.48 %
10	Coconut core	142	1.46 %
11	Sugar cane	133	1.90 %
12	Mixed waste	439	6.24%
13	Paper	525	7.52 %
	Total	6974	100.00%

Table -15: Moisture contents of the collected MSW samples

S. N	Sample Number	Moisture content (%)	Material
Sector A			
1	S1 D to D	40%	Mixed kitchens waste
2	S2 D to D	80%	Vegetable peels
3	S3 D to D	84%	Bread
4	S 4	14%	Litter
5	S 5	3.8%	Paper & board
Sector B			
1	S1 D to D	60%	Mixed waste kitchen waste
2	S 2 D to D	5%	Mixed waste (paper & plastics)
3	S 3 D to D	84%	Kitchen waste (vegetable peels)
4	S 4	30%	Mixed waste
5	S 5	32%	Sewage

Energy Content and Density of Solid Waste Components

The density and calorific value (energy content) of the collected samples of municipal solid waste are presented in Table 16.

A rough assessment of the potential recovery of energy from solid waste through different treatment methods can be made from the knowledge of its calorific value and organic fraction as per standard methods discussed below.

Table -16: Calorific value and density of MSW

S.N	Sample number	Types of MSW	Calorific value	Density
Sector A				
1	Sample 1 D to D	Mixed kitchens waste	4446.22	749
2	Sample 2 D to D	Vegetable peels	3752.31	
3	Sample 3 D to D	Bread		749
4	Sample 4 dustbin	Litter	4122.04	468
5	Sample 5 dustbin	Paper board	4100.4	-
Sector B				
1	Sample1 D to D	Mixed waste kitchen waste	4446.22	749
2	Sample 2 D to D	Mixed waste	4776.91	550
3	Sample 3 D to D	Kitchen waste (vegetable peels)	3752.31	125
4	Sample 4 Dustbin	Mixed waste	4776.91	550
5	Sample 5 Dustbin	Sewage	2085	-

Proximate Analysis

The proximate analysis was carried out using standard methods in laboratory (using Oven and Muffle Furnace) and presented in Table 17.

Table- 17: Proximate analysis of the collected municipal solid waste samples

S. No	Sample number	(VCM) in 1 gm of the sample (%)	Ash %	Fixed carbon % (in 1 gm of sample)
Sector A				
1	Sample 1 D to D	75	1.4	23.6
2	Sample 2 D to D	35	20	45
3	Sample 3 D to D	-	-	-
4	Sample 4 dustbin	78.5	12	9.5
5	Sample 5 dustbin	77	15.5	7.5
Sector B				
1	Sample1 D to D	75	1.4	23.6
2	Sample 2 D to D	84.5	4.75	10.75
3	Sample 3 D to D	35	20	45
4	Sample 4 Dustbin	65.5	27.75	6.75
5	Sample 5 Dustbin	30	50	20

Ultimate Analysis of Solid Waste Components

The results of the Ultimate Analysis was done using a State of the Art equipment, CHONS analyser in the Department of Environmental Science and Engineering, IIT (ISM) Dhanbad for the collected solid waste samples and presented in Table 18.

Table -18: Ultimate analysis of the collected municipal solid wastes

S.N	Sample number	C%	H %	S%
Sector A				
1	Sample 1 D to D	41.146	32.833	0.158
2	Sample 2 D to D	38.04	5.78	0.20
3	Sample 3 D to D	-	-	-
4	Sample 4 dustbin	45.575	3.152	-
5	Sample 5 dustbin	42.5	6.1	0.14
Sector B				
1	Sample1 D to D	41.146	32.833	0.158
2	Sample 2 D to D	40.35	6.0	0.17
3	Sample 3 D to D	41.146	32.83	0.158
4	Sample 4 Dustbin	-	-	-
5	Sample 5 Dustbin	47.6	6.3	0.21

Categorization of the solid waste samples based on the laboratory test results

The analysis results of the collected samples were used to sub-categorize the total municipal solid wastes into recyclable waste, incinerable waste, compostable waste, and land filling waste. Results are presented in Table 19.

Table -19: Waste categorization on the basis of recyclable, incineration, composting and land filling (Feb 2021)

Recyclable waste (%) by weight	Incinerable waste (%) by weight	Compostable waste in (%) by weight	Land filling waste (%) by weight
Polythene -2.91	Clothes -2.69	Kitchen waste- 23.47	Mixed waste-6.24
Glass -1.82	Coconut core-1.46	Sugar cane -1.90	Construction waste -10.80
Plastic -9.66	-	Litter -5.75	Ash - 4.73
Paper -7.52	-	Sewage waste-21.04	
Total- 21.91%	4.15	52.16%	21.77%

During the SWM process various pollutants are emitted. Vrious activities during the solid waste management are the main sources of emission of GHG and other major pollutants. During sampling period the measured mean level of particulate matter ranged between 50.7 and 89.6 µg/m3 at sources and 69.54 and 95.79 µg/m3 at downwind. Moreover, higher levels of PM were observed in the month of Feb-June than the month of October-December.]. Concentration of PM2.5 was observed to be decreased 35 m away from the source. On comparison it sowed 20% increased PM2.5 concentration at the source. Increase in level of PM2.5 raised the concern that inhalation of PM2.5 from SWM sites can cause pulmonary diseases, and other diseases among the workers and populations living within facilities of such MSWM sites. Presence of organic components in the solid waste materials is decomposed by microbes and releases GHG. So, the SWM sites are considered to be major sources of CO2 and CH4 emissions. CH4 is a major component of GHG and has 25 times more global warming potential than CO2.

Thus it shows that due to various management processes of solid waste it has a significant impact on air quality.

3. CONCLUSIONS

The household waste includes unused food, peels of vegetable, rotten food, unused papers, plastic bags, plastic material (wrappers, Likho-phekho pens, broken bucket, tub etc), unused cotton material, electronic waste, smoke, dust etc. Rotting food and other decaying organic waste allows methane and carbon dioxide to seep out of the ground and up into the air. Methane is a potent greenhouse gas and can itself be a danger because it is flammable and potentially explosive. Carbon dioxide is the most widely produced greenhouse gas. It traps heat in the atmosphere, contributing to climate change. Poorly run landfills may become nuisances because of vectors such as rats and flies which can cause infectious diseases. The occurrence of such vectors can be mitigated through the use of daily cover. Gases are produced in landfills due to the anaerobic digestion by microbes. Solid wastes are potential problem to human health from improper handling. The main problem to health is indirect and arise from the breeding of disease vectors, primarily Flies and Rats. The household waste along with industrial effluents creates specific danger of concentration of heavy metals in the food chain. Peoples are compelled to live in such area. This is not the natural process we are responsible for it. We have to concern these problems and should try to control it.

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