CAPPING vs BIOMINING OF OLD WASTE - DUMPS

India has pioneered a very simple, low-tech, low-cost, quick and eco-friendly method of remediating old open waste dumps to permanently achieve near-zero emission of landfill gases and leachate. First, fires and smoke are stopped without use of water or soil cover. Then the hills of old waste are sliced into windrows, turned 2-3 times for aeration, then sprayed with composting bio-cultures to speed up full decomposition. The waste is thus sterilized, stabilized and its volume naturally reduced by upto 40% by this eco-friendly on-site treatment above ground. This can be rapidly done anywhere without tenders, just by experienced management of existing earthmoving equipment and manpower. When the stabilized waste is screened into usable fractions, it is called "bio-mining" of old waste. This requires capex and opex for specialized screeners and can be tendered out. From 1998 till 2015 bio-remediaiton was done by the more laborious and slower method of loosening old waste layer by layer and forming it into windrows for aeration. Examples of these are described below with examples and costs, explaining its financial and environmental advantages over conventional capping of unlined waste heaps. It is now a two-decade-old well-accepted technology, deserving more carbon offsets than capping.

HISTORY OF LANDFILL CLOSURE

Worldwide, open dumps initially were covered with a layer of soil or capped (with a waterproof cover and gas extraction systems) to prevent contamination of groundwater and air. When it was found that such covered waste dumps, though protected from percolating rain or snow, still generated polluting leachate internally by anaerobic decomposition of the covered waste, new landfills began to be lined at the bottom and sides also, and later covered with an impervious cap, to form "dry tombs". Since even these may leak after 30 years, the EU has now banned all below-ground landfills, is prohibiting landfilling of organic matter which can self-generate any leachate and methane during anaerobic decomposition, and is going for above-ground composting of food wastes instead. India banned landfilling of organics in 2000!

With landfill space becoming increasingly unavailable or impermissible, because of country laws or neighbourhood objections, water is now being introduced into some historically covered dry waste dumps to accelerate their decomposition as "bioreactor landfills", in the hope that their contents can be dug out and used as compost, so that waste volumes can be minimized and landfill space can be recycled. This has its dangers. Capped landfills have exploded at Istanbul in Turkey and the Payathas site in Quezon City in Manila, even without the use of water. Bioreactor landfills only make sense for already-capped dumps abroad. With prior placement of bottom and side liners. In India, the same space-recycling can be achieved for open dumps above ground at a small fraction of the cost, or even at no cost to the Municipality.

India has wisely learnt from this historical sequence and has very progressive laws, which require **"appropriate biological processing for stabilization of wastes"**, whether subsequently used or sold as compost or not. Landfilling is restricted to non-biodegradable inert wastes or pre- and post-processing rejects. Closed landfill sites can be considered for human habitation only after fifteen years of post-closure monitoring.

India's innovative approach to closure of old waste dumps by garbage bio-mining eliminates leachate and landfill gases by performing such "bioreactor" activities above-ground, in the form of bio-treated aerobic windrows for almost total recovery of waste. This has many win-win benefits, described below, to:

* Increase available post-closure area for a new waste processing area, a scientific landfill or for alternate use. The cleared area at ground level will be three times more than a small plateau at 30 meters height above 1:3 side slopes after capping.

* Achieve near-zero emissions and leachate, instead of managing these for 30+ years. Carbon credits / offsets can be sought for permanently eliminating methane release.

* Clear the site of old waste at less than one-tenth the cost of conventional capping and totally avoid the high annual costs of landfill management, leachate treatment and gas monitoring.

* Drastically minimize the volume of old waste needing permanent burial and the requirement of scarce land for this.

* Recycle both organics and buried recyclables. Organics become coverted to soil-enriching compost or bio-earth.

* Achieve all this in one year or less, compared to 30-year management of old landfills. Site clearance by bio-mining can commence at many points simultaneously if closure is very urgent.

* Avoid the insurance costs and potential liabilities for explosion-prone capped sites

* Leave no pollution problems or environmental time-bombs for future generations.

Table 1 below lists, yearwise, thirteen sites already bio-remediated by 2010, two planned, with site-wise details and cost comparisons with the exorbitant option of capping (at Gorai, No 9):

Table 1. Open Dumps Bio-remediated By Bio-mining until May 2010

	Year	**Location**	**Area cleared, hectares**	**Waste Height meters**	**Time taken, months**	**Total cost, Rs. millions**	**Cost per cubic meter, Rs**	**Final use**
1	1997-98	Hyd,Yusufguda	2 ha	3	3.M	0.70	Rs 12	Public garden
2	2002-03	Nasik	11.6	5 mtr	3 mo	6.4 mn	Rs 15	Stadium
3	2003-04	Madurai	12	2 mtr	1 mo	0.75 mn	Rs 3	Vegetables + Fodder Grass
4	2003-04	Mumbai, Gorai	1	10mtr	3 mo	1.0 mn	Rs 16	Creation of extra landfill space
5	2003-04	Hyderabad, Autonagar	3	20mtr	2 yrs	NIL	NIL	Garbage overflow on forest land removed
6	2007	Hyderabad	19	20 mtr	< 5 yrs	NIL	NIL	Agreement signed
7	2006	Pune demo,	1	10 mtr	NA	NIL	NIL	For waste dumping
8	2007	Pune	N A	15 mtr	< 5 yrs	NIL	NIL	Agreement signed
9	2007	Gorai Capping	**16**	**17** mtr	**24** mo from April 2007	**Rs430** mn annual oper-ating costs for 30 yrs	**Rs 210** excl leachate transport	Pollution-abatement success uncertain, no gas capture till 2010. Land-grab moves have begun.

							& treatmt offsite	
10	2008-09	Faridabad:Dabva near Grain mkt milk dairy site	3.00 2.00	2.5 4.0	4 4	2.4 2.8	32 35	Public utility Housing Project
11	2009-10	Nagpur: Bhandewadi	8.00	12	8	45.00	48	Setting up of MSW processing project
12	2008-09	Alappuzha: Kavaloor	2	3	6	2.5	33	Setting up of MSW processing facility
13	2008-09	Kanpur:, Panki	14	3	9	4.2	30	" " "
14	2009-10	Bharatpur	2	2	4	1.0	25	Setting up of MSW processing facility

From 2016 to date, a new rapid hill-slicing method of aeration and bioculture spraying is in use and is described in detail in the 2017 postscript below. It has been done for Nagpur, Durg, Gurugram-Faridabad, Aurangabad Cantt, Gandhidham and Parbhani. Dimapur will begin in July 2018. No cost data per cubic meter is available as they were all done by intelligent experienced management of existing labour and earthmoving equipment. The low cost of biocultures and spraying services was met from savings in water and diesel. Biomining of the fully stabilized and volume-reduced waste was done in Durg using an existing screener and labour. Elsewhere biomining (screening) has either not yet begun or not been found necessary. Biomining is being done in Kumbakonam using a very expensive plant.

NASIK

The first well-documented bio-mining experiment was in 2002-03 at Panchvati in Nasik city, where a 28 acre site under average 4-7 meters depth of garbage was engulfed by the expanding city and the dumping of 260 tons per day over a twelve-year period needed to stop. The site was cleared of all old waste in just 120 days by a Bombay firm at a cost of Rs 6.4 million. Garbage was loosened by tractor-cultivator in six-inch layers and bulky waste removed by hand. Then the old rotted garbage (quite smelly) was sprayed with another Bombay firm's Bio-sanitiser (for almost instant odour control and no nuisance to neighbours) plus their composting bioculture which then cost Rs 28 per kg and was used at an application rate of 250 grams per cubic meter of old waste. Using a JCB (front-end loader), the loosened old waste (picked over by ragpickers for recyclables) was heaped into 2-meter-high aerobic wind-rows which were turned weekly, just as for fresh garbage windrows. This was the major cost element and the result was the same as with fresh waste: high heap temperatures attained in 2-3 days, and visible volume reduction within a week. This high reactivity of old waste seems surprising but should not be, since anaerobic landfills are known to retain their biological activity over a 15 to 25 year period, releasing measurable quantities of landfill gases in the process.

At Nasik, the soil below the old waste was excavated upto a depth of 1 meter and found to be mostly silt. So the site was closed after levelling it to a height of 1 meter above surrounding ground level to keep out flood-water, and observed for a year. Strong growth of natural vegetation on the site confirmed that there were no remaining gases or underground heat of reaction, which normally kills off the roots of plants. (Normally, nothing grows on untreated uncovered dumps, however old they are). Soon thereafter, a temporary tent-camp was erected on

the site for over 100,000 pilgrims to a once-in-twelve-years festival, with no ill effects or odour. Then an outdoor stadium was constructed over the well-settled site and there have been no problems whatsoever till date (2010).

MADURAI

Next in 2003-04 , the same firm cleared a 30-acre city dumpsite at Avaniapuram, Madurai. Old waste here was at an average height of 2 meters, and was cleared to ground level within one month, by similar bio-treatment and windrowing. The clearing cost of Rs 7-800,000 was borne by the firm which was to be allotted a compost-plant site at that location, which did not materialise. Currently the site is used to grow flourishing vegetables like egg-plant (brinjals). Incidentally, an uncultivated brinjal used for medicinal purposes is found to naturally thrive upon uncleared old waste at Nagpur, and could be usefully and economically used as pioneer vegetation to colonise freshly cleared waste dumps.

MUMBAI (BOMBAY)

A third project was in Mumbai, at Gorai, where waste dumping began many years ago in marshy land just beside a wide tidal creek. Here in 2003-04, the BMP (Bombay Municipal Corporation) paid Rs 1 million for a pilot project to clear down to ground level, one hectare of land under about 10 meters of old waste. This was done within budget in just 3 months, by a firm with compost-plant experience, again using the same biocultures, leaving a considerable amount of "bio-earth" soil conditioner for the city to use in its parks and gardens. Here too, despite the close proximity of multistory buildings which had sprung up adjacent to the Gorai dumping ground, there was no complaint of nuisance during the bio-mining operation.

This extremely quick and eco-friendly technology could have cleared the entire 17-hectare site (upto 33 meters high) to 3 meters above ground level for a cost-effective Rs 50 million at most and no off-site movement of solids or liquids. Instead, BMP engaged at a cost of Rs 170 million a quasi-Government consultancy firm which is now earning itself a bad name countrywide for its over-costly, unproven and unviable waste-management advice (see Capping Disasters at Mumbai below). Based on their recommendations, BMP awarded a tender to cap the site to a 1-in-3 slope and a 30-meter-high top of only 6.3 usable hectares instead of 17 hectares! The awarded cost of Rs 370 million excludes the cost of transporting and treating leachate at distant sewage-treatment plants not designed for such high levels of BOD, COD and contaminants, and the horrendous environmental consequences explained below.

HYDERABAD

The same year, 2003-04, an almost identical project was begun in Hyderabad by a compost-marketing entrepreneur, though both parties came to know of the others' activities only through my site visits. The firm began clearing the fringes of a huge hill of old garbage at Autonagar which received 800 tons a day of waste for decades, and in 2007 signed a five-year contract with the Municipal Corporation of Hyderabad for "bio-mining" the entire 47-acre site on no-payment-either-side basis. Excavating the waste in vertical layers from a garbage 'cliff', and using their

own biocultures on aerobic windrows along with upto 25% of fresh garbage, their bio-mining costs are covered by enriching, blending and selling the recovered organics as a compost much appreciated by farmers and flower nurseries.

PUNE

The Hyderabad firm, after a year-long demonstration and product test-marketing in nearby farmlands, signed a similar long-term contract in 2007 with Pune Municpal Corporation for no-payment-either-side levelling of their extensive hill of garbage at Urali-Devachi within five years. They have applied for renewal of the lease.

FUTURE PROJECTS

Convinced by the tremendous proven benefits of bio-mining old waste dumps, the Government of India through its JNN Urban Renewal Mission cleared funding for similar landfill bio-remediation projects at Chennai, Madurai, Kochi and Faridabad, with more to follow. The technology is no longer experimental, but mainstream now.

CARBON CREDITS

Historically, landfill-gas capture has been tried in fully bottom-and-side-lined and capped landfills. To date, at best only 55% of the landfill gas from these gets extracted for flaring or for power generation, with the rest leaking slowly into the atmosphere or causing landfill explosions.

Electricity from extracted landfill gas is everywhere financially unviable and has always needed Govt subsidy even in the US, given for environmental reasons. Since landfill-gas capture has been adopted at several locations now, the calculations for earning Carbon Credits from such reduction of methane release are well established. Calculations extend at most from 15 to 25 years, ignoring the fact that gases continue to be released to the atmosphere thereafter in annually decreasing amounts, after extraction even for flaring is abandoned.

Bio-mining or bio-remediation of waste dumps to produce ZERO emissions and ZERO leachate by totally recovering and recycling all the waste from the levelled site, leaves only limited inerts and no problems for future generations, with maximum recovery of usable space. This is a recent cost-effective technology fine-tuned in a hitherto developing country and it has not been tried in the West yet, where use of bio-cultures for composting is uncommon. So the initial investment, time and effort needed to make this very eco-friendly option eligible for Carbon Credits has not yet been undertaken by any of the firms who have developed and used the technique so far, though the potential fiscal benefits could exceed those from the landfill-gas-capture route.

It is now necessary for all the biomining operators along with the Govt of India to take the lead in ensuring that this fully well-proven bio-mining option becomes eligible for Carbon Credits, which is what is driving disastrous decisions like capping and cosmetic gas-tapping of

the creek-side Gorai dump, where waste piled above an old quarry continues to be waterlogged to a depth of 12 meters..

More importantly, should carbon credits be earned at the cost of public safety, as BMP seeks to do at Gorai?

CAPPING DISASTERS AT MUMBAI

Waterlogging of the waste

The purpose of "capping" the existing 17-hectare dump at Gorai, upto 33 meters high, is presumably to keep out water, which accelerates decomposition and methane production, and produces leachate which permanently contaminates the groundwater. Capping is a common technology, but not where garbage is bounded on one side by a tidal creek, daily lapping against the garbage heap. It is like laying a large sheet of plastic over wet sea-sand on a beach to keep the area below it dry. Of course water finds its own level, so sand beneath the plastic will remain as wet as the sea-sand around it.

That is the problem at Gorai. The bottom of the garbage heap is in some places several meters below creek level, so moisture will continuously rise up into the garbage hillock. This permanently waterlogged base of the garbage hill will accelerate methane generation and leakage from the unlined side walls.

Curtain wall

The capping plan aimed to keep water out of the heap by erecting, only on the creek side, a waterproof barrier wall of pre-cast concrete slabs going 7-8 meters down into the garbage. Since there will be massive settlement over time (especially if the intention is to extract methane for flaring or for power-generation), there will naturally be movement of the slabs and opening of the joints between them, letting in creek water and defeating the purpose. Even before that there will be water entry, because the capping contractor's deepest (43 meter) geotechnical test bore went only upto "completely weathered rock" which is quite porous, and stopped drilling 11 meters below ground level, before finding out where bedrock is found. Keeping water out and gases in would require a deep wall around the entire garbage hillock, going right down to hard bedrock, and even that would not guarantee that there will be no leakage. Constructing such a wall is technically very difficult and needlessly wasteful of time and money. Bio-mining, instead, removes the problem instead of hiding it.

Fire and flies

Work began at Gorai in late April 2007, using excavators to move waste around and level the 33-meter-high top to a uniform 30 meter height and to shape the steep sides to a one-in-three slope. Within a week of commencement, this opening-up of the heap released large quantities of methane which fed huge continuous fires and smoke. Fire-brigade efforts to douse the flames with copious water in fact aggravated the problem and generated more uncollected methane by introducing water deep into the airless mass which one wants to keep dry, apart from generating

more leachate to pollute the groundwater. This vicious cycle of methane – fire – water-dousing – more methane – and - leachate will persist daily unless there is a change in practices. Instead, if the topmost garbage had been levelled and removed by 'bio-mining' as described above, there would have been no generation of methane or leachate and no fires.

Landfill Capping Risks Exposed at Mumbai

The MSW Rules, poorly enforced, state that "Use of closed landfill sites after fifteen years of post-closure monitoring can be considered for human settlement or otherwise only after ensuring that gaseous and leachate analysis comply with the specified standards." Germany, Holland, Turkey and elsewhere have experienced the catastrophic consequences of building upon or very near to old landfills, even those closed in a state-of-the-art manner. Now India has its own horror story to add to this list.

The press in March 2007 exposed the disastrous consequences for the IT industry of a premier Mumbai builders' flaunting of the MSW Rules, with official apathy, to construct the pricey Mindspace complex on a former dumpsite at Malad. All electronic equipment has been failing with such regularity, due to corrosive landfill gases in the atmosphere, that Annual Maintenance Contracts are unobtainable. Residents are moving away because of almost monthly failures of their air-conditioners, washing-machines, electric irons or mixers. Human health effects have also been highlighted. So it is clear that "capping" the Gorai dump, which is so very near to residences, will merely convert it to an environmental time-bomb for them in a few years, for which no-one will later take responsibility, as at Malad.

It would have been far better to remove the root of the problem by converting all the waste to a useful bio-earth via bio-mining. This can still be done, though at a needlessly huge cost of removing the soil and plastic cover.

Monitoring

Despite the recent shocking Mindspace experience at Malad, there has been no move by the State Pollution Control Board to monitor air, soil and water quality at Malad or at any other waste dumps in Mumbai or Maharashtra State, although six-monthly monitoring by them is mandatory. They are evading this responsibility Statewide by claiming that open dumps are not "disposal facilities", though that has been India's only disposal method since Independence and even in 2010 in 94% of our v4378 urban Local Bodies. At Mumbai, they are not even monitoring the leachate brought to sewage treatment plants not designed for it, nor the ecological damage of releasing inadequately-treated leachate into the sea.

Energy and pollution costs of capping waste

Bio-mining requires one-time energy (diesel) for four weekly turnings of waste in aerobic wind-rows, which is then stabilized and releases no leachate, just like a sun-dried tomato. Capping makes the whole hillock anaerobic, so that all the waste in it will liquefy like a rotten tomato inside a plastic bag. All this leachate will eventually find its way into groundwater

through the unlined bottom and sides of Gorai's garbage hill. So far, all this was oozing into the creek and getting washed away by daily tides. Instead of standard leachate capture and treatment, the promoters, over 15 years of site maintenance, plan to collect and send the leachate in tankers to Mumbai's existing municipal sewage treatment plants and "pay for its treatment". These are already massively overburdened by increasing population and wastewater release, and mainly dispose of the city's liquid waste by sending it through ever-longer pipes into the sea. What will happen when leachate which has already "killed" the Gorai creek, is now let out through pipes to distant new areas? Which unfortunate fishermen, near which sewage outfall in the sea, will have to bear the brunt of the discharge of concentrated 15,000-plus-BOD leachate compared to the 250-BOD average concentration of sewage? Which Mumbaikars will get sick eating fish exposed to such leachate discharges? This will happen regardless of whether the promoters construct a leachate-treatment plant near Gorai, or add to Mumbai's daily traffic congestion and vehicular pollution load by shipping it elsewhere. It is far better to Prevent leachate formation through bio-mining instead.

Methane Generation

Flaring of methane and monitoring it is costlier than permanently avoiding its generation through bio-mining. All "waste-to-energy" plants are heavily subsidised in the US and elsewhere, all eventually at public expense. So as methane production gradually tapers off over time, the production of energy is no longer worthwhile and is abandoned after a few years, leaving the methane to be flared, and later released to the atmosphere when levels fall below that needed to feed a flame. It is far better instead to Prevent methane generation altogether through useful conversion and removal of all the waste through bio-mining.

Capping Failure and Explosion

As waste decomposes, even under a capping, its volume decreases and the heap settles, leaving a dangerous vacant pocket near the top. A leading waste-management journal[3] (Waste Management World) quotes experts as saying that "a landfill's top cover and leachate collection system will 'undoubtedly' fail. The malfunctioning of the leachate collection system (such as due to clogging) will cause the site to overflow; this would allow fluids to infiltrate and trigger a 'second wave of landfill gas generation' which could blow out the cover". Another expert claims "all liners will fail no matter how well constructed they are". That is why "Europe is phasing out organics as required by the Landfill directive, while some Member States have even banned biodegradable waste from landfill completely". Even US experts are quoted as saying what India has wisely mandated in 2000: 'If organics are separated for composting, then we can convert a problem into a solution by restoring fertility to our depleted soils.'

Pollution Risks and Insurance

The same article points out that most US regulations "do not require landfills to have assured mechanisms for post-closure funding for monitoring, maintenance and pollution clean-up, 'for as long as the wastes in the landfill will be a threat to cause groundwater pollution'. Therefore the current minimum 30-year post-closure funding period is insufficient …this is especially a problem for privately developed landfills, where the ability of private companies to provide

funding, 'effectively forever', is of concern." They also point out that "since 1996 the Netherlands has mandated 'eternal' after-care" after capping. Since Mumbai's landfill operator has a Dutch technical partner, its citizens need to inquire, in their own interest, whether "eternal aftercare" liability and insurance and disaster-management provisions have been built into the contract terms for Gorai. It is in the Government's long-term interest to make public, on its website or by other means, the complete terms and responsibilities of the persons assigned the present and future care of the Gorai landfill closure. The public today are very well informed and can bring improved solutions to the attention of the Government.

Bio-mining as a Safe Alternative to Capping

Given all the advantages listed above, it is not too late for the BMP and State Govt, to abandon all thought of capping Deonar and other open dumps and adopt bio-mining instead. Hopefully within a year some progressive Carbon Credit trader may complete the arithmetic and paperwork for claiming global Carbon Credits via the eco-friendly bio-mining route, based on the Total Avoidance of potential methane generation from the entire volumes of waste in landfills which will be stabilized by bio-mining. The Central Govt, Maharashtra State and Mumbai civic authorities should go all out to help speed up this process of accreditation, based on the same data and assumptions used for carbon credits via capping. All that is needed is political support for this progressive alternative.

2018 Postscript :

Since 2016, a new rapid bioremediation process has been developed for old dumps (wrongly called landfills) by Swachh Bharat Expert Raaginii Jaain. It was first tried on 600,000 tons of old waste at the Bhandewadi dump at Nagpur, then for 2 million tons of waste at the Bandhwari dump shared by Gurugram (Gurgaon) and Faridabad, 1 million tons at Durg, and begun at some towns in Gujarat. The process is illustrated in the photos below and a process patent is being applied for it.

First the entire hillock is mist-sprayed with GE biocultures from Geetanjali Envirotech to instantly control flies and smell, using minimum water. Then chain mounted excavators cut one meter deep trenches into the hill slopes on opposite sides of a hillock of waste. These are connected by a one meter deep trench along the top of the heap. This forms ridges between the trenches and lets air into the waste. This trenching also provides a channel for leachate within the heap to drain out to the base of the hill for treatment. GE biocultures are sprayed onto the side walls to control smell from newly exposed waste and to inoculate, right at the start, the leachate flowing out of the trenches.

After a week, when the ridges have dried and reduced about 20% in volume, the existing trenches are cut deeper and deeper. This leaves steep tall parallel ridges like slices of bread in a loaf. These are actually huge windrows quickly formed in situ. When these have drained and dried, they are dropped down into terraces by earthmovers. Later these are formed into low 2 meter windrows on available vacant or cleared ground nearby and left for biomining. In Youtube, see Almitra Patel for five-minute videos on Nagpur and Gurgaon bioremediation.

This Raaginii process of bioremediation is very rapid and cost-effective, but requires very intelligent site-specific planning for management of available space. Repeat experience is key to success. Advance drone videography of the site helps in planning and in documenting successful completion of bioremediation. The acres of land at Nagpur and Gurgaon formerly occupied by huge hills of waste are now completely covered with blocks of neat parallel rows of low windrows which are completely free of flies, odour and leachate.

What is most important and absolutely vital at all bioremediation sites is to plan for and create space to form windrows of incoming fresh waste to stabilize it. Even mixed waste can and should be stabilized in windrows with biocultures or with resh cowdung solution. This will prevent formation of a fresh hill of untreated waste. It also requires much less fuel and earthmover or excavator time and cost to form low windrows than to use the equipment for lifting the waste higher and higher, often in 2-3 stages.

All these windrows of either old or new waste must be turned weekly four times over a month so that air can reach all parts of the waste, which will then be stabilized.Waste volumes come down by upto 40% in the process. The stabilized windrows can be left onsite without harm in full compliance with the SWM Rules 2016 Sec 15 (v) (a). Simple manual screens can be provided onsite for farmers to take away the finer fraction as organic manure if they wish. Some regulation of their movement and site access is useful.

BIO-MINING OF STABILISED WASTE

If useful recovery of the dumpsite land is required, almost all the stabilized waste material can be removed offsite to clear the site. This is called biomining because of the bioculture treatment used to stabilize the waste.

Biomining is basically a process of scooping up and screening the waste into different useful fractions. The screening can be simple or highly automated to handle large tonnages. Screening usually begns with a 60 mm screen, followed by screens of 35mm, 16mm and 8mm or 4mm. A fan or air density separator removes most of the thin-film plastics which are often too dusty for recycling but are very useful for plastic roads (see below).

The finest fraction which passes through 4 or 6 or 8mm, is called bio-earth because it is about 50% fine organic matter (compost) mixed with 50% soil (inerts). It can be used as an organic manure soil improver for farmland, to increase its carbon content and vitality.

The medium-fine fraction below 16 mm and even the 16 to 35 mm fraction can be used for restoration of mining overburden which has to be re-vegetated by law. It is also very useful for restoration of salt-affected lands, if it can be affordably transported to them.

The material between 35mm and 60 mm is often stones and inerts, which can be used for road embankments or as sub-grade for roads.

The coarsest fraction, over 60mm size has a composition which varies from site to site. It might be mostly bricks and stones and glass. Or it might contain combustibles like rags and coconut shells which can be used as RDF (Refuse Derived Fuel) for say brick kilns or biomass-based power plants if any are nearby. The coarsest fraction can go through an air density separator if this will improve the usage and disposal of the different fractions.

In all cases, cities must think Waste to Health and pay for biomining operators for their services in recovering space and reducing greenhouse gases and groundwater contamination. It is important to move all fractions offsite on a daily basis, with free delivery if necessary, instead of stockpiling fractions in hopes of earning any income from them. Waste to Wealth is a mirage.