



Koshe collapsed! Tragic- but Why? and how can we avert such incidences in the future?

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Introduction

It was shocking to witness that Koshe, an open landfill in the capital collapsed, and took at least the lives of 113. Such kind of collapses or sliding are uncontrolled movements that might occur in such engineering structures because of complex geological, physical, biological and chemical interaction in the landfill leading to slope failure and instability. The consequences can be detrimental both to the communities surrounding the landfill and the environment as we witnessed some days back.

Waste is an unavoidable by-product of human activities. Economic development, urbanization, population growth and improved living standards in cities increase the quantity and complexity of solid waste generated. Even if there are a number of waste management and treatment options like waste reduction, recycling, composting and energy recovery, disposal has been the main management practice at Koshe so far.

The mass of waste in landfills is present in three phases: solid, liquid, and gas. The solid phase includes both waste and daily cover soil. The liquid phase consists of infiltrating rainwater and the moisture present in fresh waste at the time of disposal. The major source of the gas phase in landfills is the result of the microbial decomposition of damped organic materials.

This makes landfills very complex systems in which various interactive processes happen simultaneously. Gas generation because of waste decomposition changes gas and liquid pressures in landfills. Changes in liquid and gas pressures may effect porosity, total stress, gas and liquid saturations causing deformations and detrimental sliding.



Landfill sliding or collapse is not a new phenomenon. Many countries, both developed and developing have experienced that, with Ethiopia as the unfortunate one this time. To mention some, the following countries have been experiencing landfill collapses in the last two decades

Country	Year	Causalities
USA	2017	1
Guatemala	2016	24
China	2015	69
China	2008	0
Indonesia	2005	143
USA	2003	0
Philippines	2000	200
USA-Ohio	1996	0

The phenomena (landfill sliding) has plausible scientific explanations and what we need to do right now is understand the potential trigger factors and devise strategies for mitigation so that the occurrences of similar fatal incidences can be averted.

This short article is all about that, to highlight some possible scientific explanations for the collapse, and suggest some precautionary preventive measures that need to be taken.

We, the leaders of ReEco-San International (with expertise in sustainable waste management and landfill operation) believe that the established investigative team/committee will pinpoint the reasons behind among the highlighted



possible scientific explanations after undertaking field and laboratory investigation.

The followings might be the potential triggering factors.

1. The waste composition

The composition of municipal solid waste varies greatly from city to city (country to country) and changes significantly with time. The waste of Addis Ababa is mainly characterized by high content of organic and plastic wastes as other materials, like paper, glass, metals, stones and any hard materials are sorted out for reuse by the residents.

That means the waste being damped at Koshe has a lower density that leads to a reduction of surface water runoff and evaporation while increasing the risk of infiltration. The physical properties of the damped waste changes as it gets exposed to moisture inside a landfill with no functional leachate and drainage system to let the incoming water out. It has been raining in Addis Ababa at the start of March 2017 and the water level might have increased drastically leading to deformation in the landfill and then sliding.

In addition, organic and vegetable wastes have higher leachable moisture content that can lead to the rise of leachate. The city administration has reopened the site and started damping fresh waste with high content of organics. Compression of this fresh waste will definitely produce a percolable water that ends up to the inner part of the landfill. Such accumulation of leachable fluid and water in the inner part creates pressure on the bottom of the landfill, increasing the likelihood of failure in stability and ultimately collapse. With increasing infiltration and leachate, the weight of the waste in the landfill increases leading to large deformations and trigger slide within the liner system.

Biodegradable component in the solid waste undergo bacterial degradation as soon as the solid waste is placed in the landfill. During this decomposition process various physical, chemical, and biological changes takes place within the solid organic waste. As waste degrades with time, the representation of the fresh

organic matter decreases while percentage of plastics increases weakening the shear strength of the waste (the ability of damped wastes to resist forces) and probably contributing for the catastrophic incident. Studies show that shear strength reduces as decomposition progress over time. This phenomena may even compromise the future utilization of the landfill and need to be investigated thoroughly.

If the city administration considers the further use of Koshe for disposal, it should be after determining the stability of the landfill in terms of shear strength of the waste as a function of degradation/decomposition over time. There are laboratory analysis procedures for determining the shear strength and the investigative committee must make sure that this parameter will be analyzed both for the forensic purpose and to determine the future stability of the landfill.

2. Landfill fire

With 60-70 % organic composition of the waste from Addis Ababa, a high rate of anaerobic decomposition with high level of greenhouse gas production, mainly Methane is inevitable. Methane is the constituent of landfill gas posing the greatest explosion hazard and can lead to the occurrence fire. A landfill fire occurs when waste disposed in a landfill ignites and spreads. Two types of landfills fires are generally recognized. Surface fires and Deep seated fires. Surface fires typically occur in landfills that have uncovered waste with inert materials or soil. Air intrusion provides the oxygen required for increased biological activity, higher temperature and subsequently spontaneous combustion in landfills like Koshe that lacks appropriate cover. If unchecked, spontaneous combustion tend to burn deeper into the waste mass, resulting in deep-seated fires. Deep seated fires, (a fire which do not burn with open flames on the surface), are extremely dangerous as it may feed its way to vertical and horizontal waste layers, leaving plastics and paper burnt and sweeping their reinforcement effect away. Such fires creates empty compartments inside the pile and make the landfill susceptible to sliding and collapse.



Landfill fires occur frequently. In the USA there are around 8300 fires per year, and in the UK around 300 with serious environmental consequences and risk of fatal incidences. From the smoky pictures that we have seen on the news, it is likely that deep fire might have happened and contributed a lot for the collapse at Koshe too. What is more worrying is the fact that there might still be a deep seated fire in the adjacent compartments of the waste pile at Koshe and the sliding process might even not be over at this moment.

Though not common, landfill gases might pose an asphyxiation hazard either individually or in combination, if they are present at levels sufficient to create an oxygen-deficient environment. Gases like hydrogen sulfide (H₂S) are toxic to human and common in landfill gases.

3. The stability of the landfill might have been affected after the reopening for dumping

Koshe has served the city for more than 5 decades. It is an uncontrolled open dump with no proper landfill operations, poor liner and drainage/leachate collection systems. The site was meant to serve the city for 25 years, but has been used for over 50 years. It is overfilled and had been closed by the administration some months back until it was reopened in the after math of public disagreement as to the use of the new sanitary landfill at Sandafa. This activity might have affected the stability of the landfill by affecting the integrity of the landfill. When load is applied to any material, it deforms (slips or bends) a little. The more we add the more it deforms until it reaches its "peak strength." In that case, dumping more in an overfilled dumping site means, facilitating the continuation of the deformation process without increasing its resistance to load. Deformation eventually may result in several problems, such as crack formations on the cover, loss of cover and destruction of the liner. The inner part of landfill might have been then exposed to infiltration of water from rain and fresh organic waste on a regular basis. Higher pore pressure might have been created from the water infiltration without letting out the water with some sort of drainage system leading to destabilization, deformation and collapse. The site

has been exposed to load over its capacity and the basic reinforcement structures might have been destabilized by the use of heavy machineries for landfill operation.

As long as the issue with regard to the use of the new landfill at Sandafa is not solved, the administration might be forced to continue dumping waste at Koshe even if it is a risky business to do so.

4. Lack of know-how as to landfill operation and management

Landfill Management is one of the important obligatory functions of the city administration and the residents of Addis Ababa. This essential service is not efficiently performed due to limited technical, organizational and economic capabilities. The site is not protected from human interference as there is no a demarked/fenced buffer zone, people are constructing house on the cover and live in the nearby, many human scavengers scan the waste pile on a daily basis to collect reusable scrap metals and discarded food. The site lacks leachate treatment systems, has no runoff management system, lacks alternative waste treatment activities like composting, plastic recycling, energy recovery and has no any environmental pollution mitigation measure. There are some heavy infrastructural development activities going on near the landfill that also might have affected the geophysical stability of the dumping site.

All these are the manifestation of limited technical, organizational and economic capabilities for coordinated and professional landfill operation and management. Many unwise decisions might have been made and contributed for the mismanagement of the landfill and the collapse.

The table showing landfill sliding incidences and number of casualties in the introductory above show casualties related with landfill sliding happen mostly in developing countries. This is mainly due to the difference in technical, organizational and economic capabilities for sustainable landfill operations and coordinated land use planning.

Precautionary measures and the Way forward

1. Create a buffer zone and protect the dumping site from any kind of interference. Stop dumping at the site until stability and capacity is confirmed. Stopping dumping at the site is of course dependent on a long lasting solution as to the use of the new sanitary landfill at Sandafa, which is constructed according to international standard. The city needs a dumping site and at this moment, it is Sandafa, which is available.
2. Prohibit settlements in/near the landfill as risk for collapse might be there in the future.
3. Make sure that the established investigative committee performs the necessary field investigations and laboratory analysis for the determination of the shear strength of the waste, stability of the landfill and suggest feasible alternative activities that can be performed on the site up on a proper closure.
4. Stop heavy infrastructural development activities near to the landfill until the stability of the landfill is confirmed.
5. Prioritize and give incentives for the establishment of alternative waste treatment activities such as biogas production, composting, plastic/paper recycling. Landfill disposal should be the last option to be considered as a waste management strategy of Addis Ababa. Such alternative activities will divert the organic and recyclable fraction of the waste from the landfill. They can be processed and used for enhancing soil fertility and as raw materials for industrial production respectively. These approach should be the corner stone of future waste management strategy of Addis Ababa and other cities in the country.
6. Modify the landfill at Sandafa so that a production of electricity by capturing the biogas can be achieved for the benefit of the residents near to the site.
7. Focus on institutional capacity building and upgrade the technical, organizational and economic capabilities of staffs to guarantee scientifically sound decision-making processes for good and safe landfill operational practices.

8. Involve Ethiopian professional as to devising strategies for the establishment of a sustainable waste management practices for the city that guarantees the socio-economic and environmental benefits.

In conclusion, the goal of this article is just to highlight some possible scientific explanations behind Koshe incident to anyone wondering why this happened and propose precautionary measures that needs to be taken until investigative committee pinpoints the cause/s after a careful investigation.

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