Climate change impact of waste management - A study based on Tajikistan's pharmaceutical waste management

Authors: Devni Acharya[1] | Dr. Kristian Steele[2] | Dr. Christoph Hamelmann[3] | Tedla Mezemir Dante[4]

[1]*Environmental Consultant, Resource & Waste Management, Arup*
[2]*Senior Analyst, Advanced Technology & Research, Arup*
[3]*Regional Practice Leader HIV, Health and Development, UNDP Regional Centre, Europe and the CIS*
[4]*Program Manager - Global Fund Grants, UNDP Tajikistan*

ETLog©

Introduction

The United Nations Development Programme (UNDP) is developing a waste management planning tool for its Global Fund operations that works to improve waste treatment practices while also understanding the climate change impact associated with different disposal strategies. This study has supported the initiative by developing a first set of carbon factors for different waste management strategies to inform the planning tool. The project has focused on pharmaceutical waste management of antiretroviral tablets in Tajikistan.

With this focus the study has reviewed the climate change impact of three waste management scenarios include onsite small scale incineration that has limited appeal due to its toxicological footprint and two alternatives that offer improvement.

The study has found the carbon footprint results for the scenarios to have a negative correlation between the issue of climate change and the preferred strategies from the toxicological safeguarding perspective.

These findings point towards the complex issue of waste management and as such the study is a good example of environmental safeguarding demanding a comprehensive view that weights the relative minor/ moderate gains in one area (climate change) with the risks related to another (toxicological footprint). The solution therefore is to look for greenhouse gas emissions savings between the preferred alternatives and therefore forming an effective waste management strategy.

Within the family of tools that UNDP-GF is developing on waste management and New Funding Model grant planning, the study shows that it is feasible to provide a carbon calculation module that enables greenhouse gas emission calculations of different waste management strategies.

Study scope

The study scope has been developed within the working context of the UNDP Tajikistan Global Fund (GF) programme. In Tajikistan, antiretroviral (ARV) tablets used for HIV treatment were identified as high value procurement items both in quantity and cost. As such, ARV tablet waste and its waste management practice were identified as a suitable priority category.

The materiality of this waste was identified to include:

- pharmaceutical tablets
- blister packs that enclose the ARV tablets
- patient information leaflets
- small cardboard boxes containing the above three items
- larger corrugated cardboard boxes used for transporting the ARV medicines

The three strategies for which carbon factors have been calculated are detailed below.

1. **Onsite small scale incineration:** models the carbon factor associated with common pharmaceutical waste management currently taking place in Tajikistan. The waste is treated and disposed of at the hospital or health centre where it is generated, or alternatively at a larger central district hospital where facilities are available. This strategy involves treatment of the waste using basic waste infrastructure including small scale incinerators using biomass fuel, and without emission control and in some cases open burning. The residual ash from the incineration or burning process is then buried in an ash pit within close proximity[1].
2. **Standard solution / advanced incineration:** has been modelled to reflect the approach that Tajikistan is working towards. This involves a national pharmaceutical waste take-back system that uses reverse logistics; supply vehicles transport the medicines to hospitals and health centres from a central warehouse, which then simultaneously collect any pharmaceutical waste to bring back to the central warehouse. The waste is then accumulated and periodically treated in an advanced incinerator with a high temperature two-chamber system with basic flue-gas treatment and which uses diesel fuel to aid combustion. The fly ash and incinerator bottom ash is then disposed of in a designated area of a landfill.
3. **Standard solution / encapsulation:** follows the same system set out in strategy two but sees treatment through encapsulation by filling drums with 75 % waste material and 25 % immobilising material. The drums are then disposed of in landfill.

Both strategies two and three have been assumed to be in line with World Health Organisation guidelines[2].

[1] Pieper, Ute., ETLog, (2013) Rapid Assessment Road Map for HIV, TB and Malaria GF grants (waste sector)

[2] World Health Organisation (1999) Safe Management of Wastes from Health-care

Medical supply central warehouse

Encapsulation of waste in metal casing using cement as the immobilising material

Storage of medical supplies inside a central warehouse

An outline estimate was also undertaken for the carbon dioxide equivalent (CO_2e) emissions relating to the reverse logistics of the standard solution waste management strategies.

Calculation approach

A carbon factor was calculated for each of the three waste management strategies to assess and compare their climate change impact. The carbon factors were computed by summing together the CO_2e emissions for each stage in the strategy that produced CO_2e emissions. Undertaking this calculation required that waste material flow quantities were determined.

Pharmaceutical waste inventory

The UNDP-GF procurement department in Tajikistan estimate that 5 % of all pharmaceutical products expire. This value was further checked by UNDP central procurement, and the rapid assessment studies by ETLog for both Tajikistan and Zimbabwe and was found to be accurate. It was therefore assumed that 5 % of ARV tablets procured under the UNDP-GF grant in Tajikistan expire and require waste management. Using 2012 procurement figures developed by the ETLog study, this amounted to approximately 40 kg of tablet waste with an estimated 4:1 ratio between active pharmaceutical ingredient (API) and excipient content. This ratio was determined by establishing a weighted average based on the chemical composition of all procured ARV types by UNDP-GF in Tajikistan in 2012.

Packaging waste

By using average mass ratios between pharmaceutical tablets and their packaging, the total packaging waste amounted to approximately 78 kg. The blister pack cavities were assumed to be made out of polyvinyl chloride with the film covers made out of polyvinylidene chloride.[3,4] The small cardboard boxes were sized to hold blister packs enclosing a total of 60 tablets (as do the majority of ARV medicines procured in 2012) and the paper patient information leaflet. This was then used to determine the amount of larger corrugated cardboard box packaging required for transporting the ARV medicines.

Strategy: Onsite small scale incineration

The small scale incineration or open burning of the waste was modelled under a 70 % (by mass) combustion efficiency, with the remaining 30 % (by mass) becoming residual ash requiring disposal. This combustion efficiency was applied to correspond to the lower bound combustion efficiency of a typical municipal incinerator.[5] Small scale incineration and open burning may not provide optimal oxygen conditions for efficient combustion to take place thereby producing a higher percentage of ash than if optimal oxygen conditions were present.

With the composition and mass of the tablet waste known, carbon dioxide emissions were calculated based on the complete combustion of its API and excipient constituents. Other products of combustion were assumed to have negligible climate change impact. The CO_2e emissions relating to the combustion of the packaging materials were calculated using data from the life cycle assessment tool, GaBi (version 4.0)[6]. The CO_2e emissions relating to the disposal of the residual ash in an ash pit were modelled as inert material being disposed of via landfill[7].

Strategy: Standard solution / advanced incineration

When modelling advanced incineration treatment, the incinerator was assumed to be autothermic with no energy recovery associated with the process. In contrast to the combustion within the onsite small scale incinerator, a higher combustion efficiency of 80 % (by mass) relating to the upper bound combustion efficiency of a typical municipal incinerator was applied to the process due to the higher level of process control present with advanced incineration.

The CO_2e emissions from the combustion of the tablet and packaging waste streams were calculated with a similar process described above for onsite small scale incineration.[5] The CO_2e emissions relating to the landfill disposal of the 20 % (by mass) residual ash (fly ash and incineration bottom ash) from the incineration process was modelled as an inert material disposed of via landfill. The landfill was assumed to be a general waste landfill with a protective leachate barrier.

[3]World Health Organisation, WHO List of Prequalified Medicinal Products [online] Available at: apps.who.int/prequal/query/productregistry.aspx?list=ha, Accessed March 2014

[4]Pilchik R. (2000) Pharmaceutical Blister Packaging, Part I: Rationale and Materials, Pharmaceutical Technology, November 2000

[5]Department for Environment, Food and Rural Affairs (2013) Incineration of Municipal Solid Waste

[6]PE Europe GmbH and IKP University of Stuttgart (2003) GaBi 4.0

[7]The Chartered Institution of Wastes Management, Incineration [online] Available at: www.ciwm.co.uk/CIWM/InformationCentre/AtoZ/IPages/Incineration.aspx, Accessed March 2014

ETLog©

Small scale incineration of waste

ETLog©

Small scale incinerator and ash pit

Strategy: Standard solution / encapsulation

The encapsulation was modelled in high density polyethylene (HDPE) drums[8] with 75 % of each drum filled with waste material. The remaining 25 % of each drum was assumed to be filled with cement, which was selected as the immobilising material.

Embodied carbon values[9,10] were used to estimate the CO_2e emissions associated with the manufacture of the HDPE drum and cement quantities required. For the purposes of this study, it was assumed that no landfill gas would be produced from the encapsulated waste when placed in landfill. However, CO_2e emissions from disposing of HDPE material in landfill was calculated and included in the carbon factor total. The larger corrugated cardboard boxes were modelled to be disposed of via landfill as a separate waste stream. Again, the landfill was assumed to be a general waste landfill with a protective leachate barrier.

Study findings

The carbon emissions calculated for each strategy along with the emission contributions from each of their stages are summarised below. These are total calculated emissions for the recorded ARV Tajikistan waste stream in 2012. For reference a carbon factor for each respective ARV disposal strategy is also provided.

The standard solution of advanced incineration has the highest carbon emissions associated with it at 159.6 $kgCO_2e$. The onsite small incineration strategy has emissions of 97.6 $kgCO_2e$ which is 39 % lower than that of the standard solution /advanced incineration strategy. The lowest carbon emissions level comes from the standard solution / encapsulation strategy at 47.8 $kgCO_2e$, which is just over 50 % lower than the onsite small incineration strategy and 70 % lower than the standard solution /advanced incineration strategy modelled. This indicates that the waste treatment process of incineration is a more carbon intensive way of treating ARV pharmaceutical waste and its accompanying packaging waste streams than if the waste were to be encased in drums with an immobilising material.

However, when considering these waste management options in terms of preferences set out in the waste hierarchy, encapsulation would be seen as the least preferred option. This is since encapsulation would see the waste streams being disposed of via landfill. Landfilling is an option that potentially locks away resource that could otherwise be utilised as feedstock to industrial processes as well as having land use implications.

In contrast the standard solution / advanced incineration strategy which is the most robust strategy modelled - it sits higher up the waste hierarchy than the encapsulation strategy and safeguards against health and safety issues that small scale incineration or open burning does not - is found to have the highest carbon factor. The largest contributor to its carbon factor comes from emissions relating to diesel fuel incineration (~30 %). This is followed by emissions from API incineration (~28 %), packaging incineration (~27 %) and then excipient incineration (~15 %). The emissions corresponding to disposing of the residual ash via landfill (i.e. from material degradation in

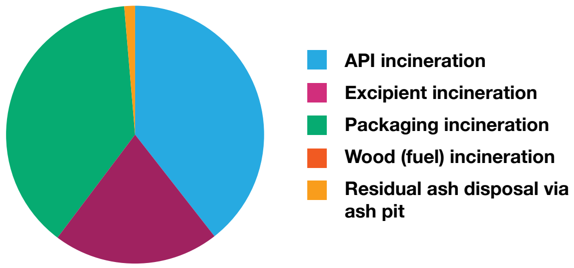
[8] The Cary Company (2011) Product Definition Sheet: 055C400UL1

[9] Arup (2013) Project Embodied Carbon Calculator Version 2.3

[10] University of Bath (2011) Inventory of Carbon & Energy (ICE) Version 2.0

Strategy: Onsite small scale incineration

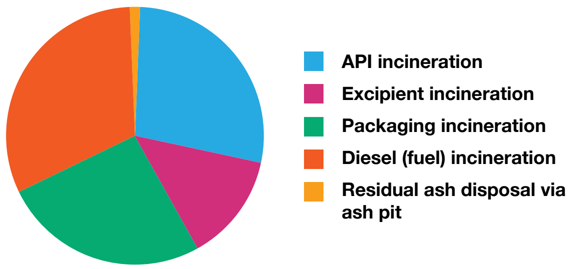
Stage	$kgCO_2e$ emissions
API incineration	38.5[1]
Excipient incineration	20.5
Packaging incineration	37.6
Wood (fuel) incineration	0.0
Residual ash disposal via ash pit	1.1
Total emissions	**97.6**



The carbon factor for ARV onsite small scale incineration is 0.8 $kgCO_2e$ / kg of waste arising.

Strategy: Standard solution / advanced incinerator

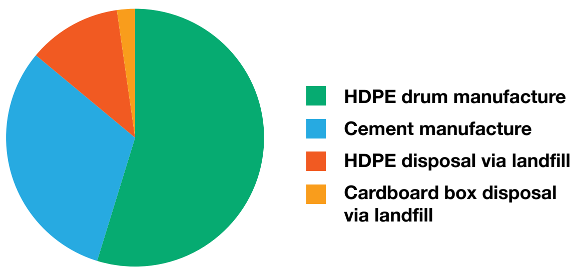
Stage	$kgCO_2e$ emissions
API incineration	44.0
Excipient incineration	23.4
Packaging incineration	43.0
Diesel (fuel) incineration	48.6
Residual ash disposal via ash pit	0.5
Total emissions	**159.6**



The carbon factor for ARV disposal in the advanced incinerator is 1.4 $kgCO_2e$ / kg of waste arising.

Strategy: Standard solution / encapsulation

Stage	$kgCO_2e$ emissions
HDPE drum manufacture	26.2
Cement manufacture	15.9
HDPE disposal via landfill	5.1
Cardboard box disposal via landfill	0.6
Total emissions	**47.8**



The carbon factor for ARV disposal via encapsulation is 0.4 $kgCO_2e$ per kg of waste arising.