Review of Elephant Ivory Destruction Methods
CITES Secretariat[1]

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1. Introduction

In 1989, international commercial trade in elephant ivory was banned by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Poaching of elephants and illegal trade in their ivory however continues to impact global elephant populations, resulting in their decline. Since 1989, there were many events of ivory destruction around the world, involving more than 263 metric tons of ivory that have been destroyed in at least 21 countries and territories.[1]

In accordance with the guidance provided by Resolution Conf. 17.8 on *Disposal of illegally traded and confiscated specimens of CITES-listed species,* confiscated and accumulated dead specimens of Appendix-I species such as elephant ivory should be disposed of "only for *bona fide* scientific, educational, enforcement or identification purposes, and save in storage or destroy specimens whose disposal for these purposes is not practicable".

The purpose of this document is to review destruction methods.

In recent years, CITES Parties have increasingly used ivory destruction to discourage the illegal ivory trade. This report considers seven approaches to elephant ivory destruction and evaluates each in terms of its practical advantages / disadvantages and overall environmental impact. CITES Parties have used some of these approaches in the past, others have not. The report does not include an economic assessment of each approach.

Prior to any destruction of ivory stockpiles, Parties should take account of any recommendations of the Conference of the Parties concerning the collection of samples for forensic research and collaborating with relevant forensic research institutions. If any ivory to be destroyed has been marked, either in accordance with recommendations from the Conference of the Parties or national law, these marks should be recorded as this information may be useful for the purposes of law enforcement cooperation at a later date.

2. Background: chemistry and physical properties of ivory

Destruction techniques are often influenced by the chemical and physical properties of the material to be destroyed. The ivory tusks of an elephant are essentially the incisors that grow in the nasomaxillary complex of bones throughout its entire life.[2] The major bulk of ivory is dentine which is composed of inorganic and

1 Based on a report by Jack Caravanos, DrPH, CIH, New York University, School of Global Public Health, New York, New York

organic fractions.[3] The organic composition has a diamond-shaped pattern, better known as Schreger structure, which can be observed on the cross-section of elephant ivory.[3] This structure is a unique configuration of dentinal tubules, which is a type of organic fiber.[3] These organic fibers have diameter ranges from 0.8 to 2.2 microns and provides high elasticity to the ivory tusk.[3] The inorganic component of the dentine is dahllite, a form of calcium phosphate carbonate with the chemical formula; Ca10(PO4)6(CO3)H2O.[4] Essentially it provides the hardness and strength associated with the ivory tusk.

The basic structure and components of the ivory tusk are well established. In 1999, E.J. Raubenheimer detected 16 elements in the inorganic fraction of ivory.[2] Table 1 below contains the inorganic elements in ivory, taking 64 fragments of ivory from six different geographical locations in Africa and identified by atomic absorption spectrophotometry. Research also shows that the ivory tusks of elephants living in different habitats have different properties and inorganic elements.

Table 1: Composition of Inorganic Elements in African Elephant Ivory

Major Elements (4)	Common Elements (6)	Trace Elements (6)
Calcium	Zinc	Cobalt
Phosphate	Arsenic	Cadmium
Magnesium	Lead	Manganese
Fluoride	Aluminum	Mercury
	Chromium	Molybdenum
	Copper	Nickel

In addition to inorganic elements, elephant ivory contains organic matter in the form of various proteins, amino acids and collagen. While the inorganic/organic chemical composition of ivory varies (there is soft ivory and hard ivory), the estimates range from 60/40 to 70/30.[5] This means that by weight, organic molecules, which are combustible, represent at most 30-40 percent of the ivory mass[6]; the remaining being incombustible inorganic compounds as those listed in Table 1. In short, ivory has a low British thermal unit (BTU) value and does not burn readily (i.e. self-combust). As comparison, the human body contains about 11% minerals by weight and when dried out, is very combustible.

As regards the physical parametres of elephant ivory, the material has a Mohs scale of hardness rating of 2-3 putting it with materials such as gypsum and human nails. Of course, the simplest comparison is to human teeth.

The specific gravity (density) of elephant ivory ranges between 1.8 - 1.9 grams/millilitre and as such, sinks in water. As a reference marble and granite have specific gravities of approximately 2.7.

These chemical and physical properties are provided as background as they may affect any destruction method utilized.

3. Assessment of destruction technologies

Various countries have engaged in ivory destruction events as a way to discourage elephant poaching and illegal trade in ivory, and to draw public attention to the scale, nature and impacts of the serious crimes that lie behind these ivory confiscations. The majority of these events displayed the burning of very large piles of elephant ivory. This section will present the advantages and disadvantages of various ivory destruction options with specific attention to adverse environmental impacts (i.e. air pollution, water contamination and land contamination), both in terms of human health as well as ecological impacts.

a. Burning of ivory

Description of Process: In 1989, Kenya took the first step in animal ivory destruction and burned a 12 metric ton pile of elephant tusks[7]. Since then, ivory burning has become a frequent method for countries and territories wishing to destroy confiscated ivory stockpiles:

- 1992, Zambia burned 9.5 tons of ivory stockpile
- 2011, Kenya burned another 5 tons (12 tons in 1989)
- 2012, Gabon burned 4.8 tons[8]
- 2014, Chad burned 1.1 tons ivory stockpile[9]
- 2014, Hong Kong began monthly burns destroying 29.6 tons of stockpile[10]
- 2015, Kenya burned approximately 15 tons big stockpile of ivory [11]
- 2015, Ethiopia also burned 6.1 tons of ivory stockpile[12]

- 2016, Kenya burned 105 tons of ivory stockpile [18]

Burning of the ivory stockpile is a bold, eye-catching political display that is meant to send a message against elephant poaching and illegal trade in ivory. It can be a powerful publicity tool if the media coverage of destruction events is effective enough[13]. However, the mechanism of burning ivory is much more complicated than anticipated.

As mentioned in section 2 of this document, ivory is a rather durable substance; a good analogy being human teeth[14]. Given that it is made up of at least 65% non-combustible material (i.e. minerals), it needs an accelerant. Experiments conducted in 2008 conducted under controlled conditions confirmed the difficulty of burning ivory[15]. Oxygen-enriched propane generating 982° C (1,800° F) was used to burn an ivory tusk. The results revealed a thermal decomposition decay of only 7 grams per minute (0.25 once/minute)[16]. On this basis, depending on the duration and temperature of the fire, it could take months to burn 1 ton of ivory stockpile[17]. Burning large stockpiles of ivory cannot take place without the addition of many litres of diesel fuel or other accelerant.

Given the poor combustibility of elephant ivory, open air burning does not yield the high destructive effect warranted by the negative environmental impacts. For example, in the 2016 Kenya burn, if we assume the ivory consisted of 30% organic matter and 105 tons were "burned", then this would leave approximately 73.5 tons (0.7 x 105 tons) of uncombusted material remaining. This material would be distributed within the resultant ash pile and the released airborne particulates. This technology will render the elephant ivory unusable only if it is subjected to sufficiently high temperatures and periods of burning.

Advantages:

- Burning is a strong visual discouragement.
- It is low technology that is relatively easy to administer.
- It can be done locally with no special land requirements.
- When done properly, it can render ivory unusable.

Disadvantages:

- Large amounts of accelerant fuel are needed (petrol, diesel) to initiate and sustain combustion.
- Substantial amounts of un-combusted ivory remain.
- Substantial amounts of ash need further disposal.
- Flammability hazard needs managing.
- Many safety concerns: accidents, collapsing pile, burns, all presents worker risks.

Environmental Impacts:

- Potential toxic exposure to accelerant fuel(s).
- Burning produces tremendous quantities of air pollution emitted, including
  - Total suspended particulates
  - Fine particulates (PM2.5)
  - Oxides of nitrogen
  - Carbon monoxide
  - Sulfur dioxide (from accelerant fuel source)
- The air pollutants generated can be transported long distances and impact other communities and crops.
- The air pollutants generated can significantly affect human health and welfare.

Summary:

- Burning of ivory is a viable destruction method if administered correctly but has considerable undesirable environmental side-effects.

b. Crushing of ivory - Mechanical method

Description of Process: Crushing is another commonly used ivory destruction method and can be further divided into mechanical or manual processes.

In 2012, Gabon crushed a larger stockpile of ivory, about 4.8 tons [18] followed by an event in 2013 in the Philippines. The Philippines event was the first non-African country to introduce crushing as an ivory destruction method. They used a road roller and the bucket of a mechanical digger for this purpose [19]

In the same year, the U.S destroyed 6 tons of ivory in Denver, Colorado and one year later, more than 6 tons of ivory was destroyed in Beijing, China [20]. France was the first European nation that publicly crushed more than 3 tons of ivory in 2014[21]. As ivory destructions events continue, a pattern seems to reveal itself. It seems that African countries are more inclined to burn their ivory stockpiles, while other parts of the world tend to crush it. Is the crushing more effective than burning? It turns out the crushing is not without its challenges, especially when the stockpile is very large, as is the case in African countries. In 2013, the U.S. used massive rock crushers to pulverize the ivory piles [22] Given that elephant ivory is much softer and more brittle than granite and other rocks, these mechanical crushing units can operate faster and more efficiently.

The ultimate goal of crushing, whether, manual or mechanical, is to produce ivory particles of no economic value. However, once crushed, the material must still be carted away and disposed of properly. Fortunately, crushed elephant ivory is not considered hazardous waste by some environmental agencies (US EPA and EU) so on-site burial is possible. However, care must be taken to ensure that any residual matter does not enter illegal trade and pulverization and/or incineration at high temperature may be needed to ensure that this is the case. One notable feature is that, as the material has not undergone any chemical alteration, given the very high concentration and purity of important inorganic elements such as calcium, phosphate, and magnesium, these minerals can be identified and recycled.

Advantages:

- Almost complete destruction
- Mobile crushing equipment is readily available and can travel to sites.
- Large scale crushing equipment is commonplace in stone quarries where base material for cement manufacturing is used.
- Large mechanical rock crushing units have proven fast and efficient because elephant ivory is much softer and more brittle than granite and other rocks.
- Essentially, climate friendly and with almost zero environmental emissions (except the fuel for the mechanized crusher).
- Crushed elephant ivory is not considered hazardous waste by some environmental agencies and on-site burial is possible.

Disadvantages:

- Material needs subsequent disposing and could be of commercial value.
- Care needed to ensure that residual matter does not re-enter illegal trade.
- Specialized skills needed to operate equipment.
- Some crushing tools (e.g. road rollers) are relatively inefficient and further action may be needed to fully destroy the ivory.
- Safety concerns: slips, trips, falls, and flying debris present worker risks.
- Noise: rock crushers are very loud and hearing protection is usually necessary.

Environmental Impacts:

- Inorganic dust emissions from crushing operation, with little or no environmental impact (except the fuel for the mechanized crusher).

Summary:

- A viable and environmentally sound method for elephant ivory destruction, with low risks.

c. Crushing of ivory - Manual

Description of Process: Manual crushing refers to humans physically striking and breaking ivory tusks into small and unusable objects with a hammer or other equivalent device. Ivory, as stated earlier, is brittle and easily broken by these tools as is human bone. For small scale operations, this may be a reasonable option. During the 2013 Philippines crushing event, it took many hacksaws, a small roller, and a backhoe to break up the ivory stock. And ultimately the remaining debris still had to be incinerated [23]. It is a quite labour intensive method and may present risks of pilfering the ivory. This technology will in most cases render the ivory unusable, but additional steps such as pulverization and/or incineration at high temperature may be needed as noted above.

Advantages:

- Low dust generation.

– In most cases, complete destruction.
– Requires little technology and skill.
– Relatively inexpensive.
– Labour pool is readily available.

Disadvantages:

– Material needs subsequent disposing and could be of commercial value.
– Time-consuming and not amenable for large quantities.
– Theft / pilfering risk is high.

Environmental and Human Health Impacts:

– Noise: rock crushing is loud and may exceed regulatory levels. Hearing protection is usually necessary.
– Safety concerns: flying debris presents worker risks, accidents.

Summary:

– A viable and environmentally sound method of disposing of elephant ivory, only where small quantities are involved.

d. Chemical Treatment

Description of Process: Chemical treatment has been widely used for the destruction of persistent organic pollutants, pesticides, polychlorinated biphenyls (PCB) and even chemical warfare agents. With regard to ivory, strong acids, alkalies and oxidant chemicals have the ability to dissolve the organic components of bone (i.e. proteins) and theoretically can be used as a destruction option. The inorganic matrix of ivory is more difficult to "dissolve", but possible. The destruction is accelerated when supplemented with high heat and pressure. Breaking the ivory into smaller pieces increases surface area and will also increase dissolution rates. A literature search revealed no published papers on this approach; however, it is a common hazardous waste disposal technology. The challenges for large scale application of chemical destruction of ivory include, specialized vessels and equipment, cost of the reagents and trained personnel. This technology will render the elephant ivory unusable.

Advantages:

– Almost total destruction of ivory can be achieved.
– Technology readily available.
– No air emissions.
– Manageable industrial process.

Disadvantages:

– Expensive.
– Specialized equipment, vessels and trained staff needed.
– Reagents much be purchased and stored properly.
– Reagents are toxic and must be handled with care.
– Residual waste will be classified as hazardous and must be neutralized.
– Unlikely all ivory will be dissolved / destroyed.
– Relatively slow and time intensive.
– Ivory and reagents may have to be transported to the processing site.

Environmental and Human Health Impacts:

– Enhanced worker protection needed due to corrosive and toxic agents.
– High likelihood of spillage and land contamination.
– Final wastes need neutralizing and cannot be readily disposed of.
– It is fundamentally a high-risk technology.

Summary:

– A non-viable and environmentally unsound method for ivory destruction, with relatively high risks.

e. Land Burial

Description of Process: The natural environmental sink for ivory is, of course, land destruction or burial. With the exception of damage done by a few insects, ivory is relatively immune to natural decay and extremely durable. The fossilized remains of prehistoric animals continue to be discovered millenniums later. Therefore, the simple burial of ivory will not render it unusable. However, deep land burial may be an inexpensive and applicable option given the correct terrain. The concept here is to render the material inaccessible by either disposing in pre-dug deep wells or excavation sites. However, future inaccessibility is questionable and will always present a risk given raw ivory is quite valuable at hundreds of euros per kilogram.[24]

Advantages:

– Low technology solution.
– Excavation equipment often readily available.
– Adaptable to many terrains and climate zones.

Disadvantages:

– Strong motivation to recover disposed ivory.
– Depending on site, future accessibility of material may require monitoring efforts.
– Does not decay quickly.

Environmental and Human Health Impacts:

– Very low environmental impact (no chemicals uses, no air emissions).
– Some occupational health and safety risks during "construction" possible.

Summary:

– Environmentally sound method of disposing of ivory, but with risks that material could be retrieved considered non-viable.

f. Destruction by Disposal at Sea - Shallow / Continental Shelf

Description of Process: For purposes of this assessment, disposal at sea has been divided into shallow and deep-sea disposal. Shallow disposal at sea is the direct release of intact ivory materials onto the continental shelf; including onto deep coral reefs. Given the possible accessibility and recovery of ivory at very shallow disposal, the goal is to dispose of the material at depths greater than 40 metres. Recreational divers usually do not venture more than 39 metres (130 feet). Most coral reefs are shallow and lie within the euphotic zone of the continental shelf where sunlight can sustain marine life. Disposal onto reefs less than 18 metres deep may render the ivory accessible through either persons using SCUBA or advanced snorkeling practices.

Ivory can be a very valuable resource for coral reefs building and ecological marine recovery and/or sustainability. Numerous commodities have been disposed of off-shore to help build and recover reefs including obsolete New York City subway cars, out-of service shipping containers and even marine vessels.[25] Given the chemical composition of ivory, such material will unlikely have a negative ecological impact and most probably enhance marine ecosystems. Additionally, given most seaside communities have existing shipping capabilities, this option does not require a large-scale infrastructure investment. Evidence suggests that immersion of ivory in sea water does not result in its complete destruction and as this method may not render the ivory inaccessible the site for any disposal should be carefully selected and disposal in deep sea may be preferred.

Advantages:

– Relatively low technology.
– Recovery of material may require considerable logistical effort.
– Helps to build/rebuild marine ecosystems.
– No pre-treatment of ivory necessary (whole ivory disposal).
– Numerous sites available.

Disadvantages:

– Fuel and labour cost to bring material to disposal site may be costly.

– For landlocked countries, ivory transport to a coast may be costly.
– Security risks whilst material is being transported for disposal.
– Theft / pilfering risk.
– Possibility of ivory being recovered.

Environmental and Human Health Impacts:

– Very low environmental health impacts.
– Very low adverse ecological impacts.

Summary:

– Environmentally sound method of disposing of ivory, but with risks that material could be retrieved and therefore considered non-viable.

g. Destruction by Disposal at Sea - Deep Sea or Continental Slope/Rise

Description of Process: Deep ocean disposal refers to the direct dumping of ivory onto either the continental slope or rise, or directly onto the oceans abyssal plain. Essentially disposing of ivory at depths greater that 60 metres. The average depth of the Earth's oceans is approximately 3,500 metres making recovery essentially impossible. Given the possible elevated costs of reaching these sites, several possible scenarios include using existing shipping traffic to expedite disposal and/or partnering with the personal Cruise Line industry to help facilitate disposal. The actual disposal may consist of either offloading individual ivory pieces into the ocean or unloading an entire 12 metre shipping container full of ivory into the ocean. Numerous possibilities exist. The added awareness of permanent disposal, using the Cruise Line Industry, would bring improved and heightened awareness to the illegal ivory collection and trade. Lastly, given the open ocean is often only less than 50 kilometres offshore, even contracted shipping makes this a viable option. This technology will render the ivory inaccessible.

Advantages:

– Relatively low technology.
– Recovery of material likely to require considerable logistical effort.
– No pre-treatment of ivory necessary (whole ivory disposal).
– Unlimited sites.
– Possible marine benefit.

Disadvantages:

– Fuel and labour cost to bring material to disposal site may be costly.
– For landlocked countries, ivory transport may become costly.
– No immediate benefit to building or rebuilding marine ecosystems.
– Theft / pilfering risk.
– Possibility that ivory could be recovered, although low and improbable.
– Some security risks whilst material is being transported for disposal.

Environmental and Human Health Impacts:

– Very low environmental health impacts foreseen.
– Very low adverse ecological impacts foreseen

Summary:

– Environmentally sound method of disposing of ivory, but with slight risk that material could be retrieved and therefore considered undesirable.

4. Conclusions

The assessment of ivory destruction approaches presented above yields only a few viable options. Most notably; *Mechanical Crushing* seem most promising when looking at effectiveness and environmental impacts. Mobile rock crushing equipment is commonplace given their use within the building and road construction industry. Adapting these units to destroy elephant ivory is relatively simple with no special modifications. Disposal of crushed material, provided it is sufficiently pulverized, should be relatively simple. In earlier tests using stone crushers, the waste material was mixed with cement to ultimately produce

concrete. Manual Crushing (i.e. by hand) is unlikely to be a feasible option given the high volume of ivory and large labour requirements. Theft of ivory pieces may be a problem with the manual crushing operation.

For countries that border on large water bodies, destruction by *Disposal at Deep Sea* may prove the simplest and most direct way of disposing large quantities of animal ivory. The likely existence of commercial seaports within these countries offers an existing system to implement such a practice. There is a very low environmental impact of the destruction by *Disposal at Deep Sea* option. However, the likely associated security costs, risk of corruption and theft and possible retrieval of such ivory, make this an option that does not seem desirable.

It is important to keep in mind that, if selected as a disposal option, ivory destruction is episodic and unlikely to be an ongoing daily or monthly event. Therefore, the selection of an environmentally friendly method should be evaluated within that context. The options for the environmentally sound destruction of elephant ivory presented above must, of course, also be considered in economic terms.

Mechanical Crushing seems most likely to meet the requirements of permanent and safe destruction method for ivory, with minimum environmental health or ecological risk.

5. References

[1] Dominic Smith. "Kenya Burns Largest Ever Ivory Stockpile to Highlight Elephants' Fate." The Guardian, The Guardian, 30 Apr. 2016, www.theguardian.com/environment/2016/apr/30/kenya-to-burn- largest-ever-ivory-stockpile-to-highlight-elephants-fate. Accessed 13 Nov. 2019.

[2] Raubenheimer, E.J.. "Morphological aspects and composition of African elephant (Loxodonta africana) ivory." Koedoe [Online], 42.2 (1999): 57-64. Web. Accessed 21 Apr. 2020

[3] A. BANERJEE, G. BORTOLASO. W. DINDORF.. "Distinction between African and Asian Ivory." Elfenbein Und Artenschutz - BfN. www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/skript228.pdf. 37-49. Web. Accessed 21 Apr. 2020

[4] Espinoz, Edgard O., Mann, Mary-Jacque.. "Identification Guide for Ivory and Ivory Substitutes .". Web. Accessed 22 Apr. 2020

[5] Matienzo, L. J., & Snow, C. E. (1986). The chemical effects of hydrochloric acid and organic solvents on the surface of ivory. Studies in Conservation, 31(3), 133-139.

[6] Tripati, Sila, and Ian Godfrey. "Studies on Elephant Tusks and Hippopotamus Teeth Collected from the Early 17th Century Portuguese Shipwreck off Goa, West Coast of India: Evidence of Maritime Trade between Goa, Portugal and African Countries." Current Science, vol. 92, no. 3, 2007, pp. 332-339. JSTOR, www.jstor.org/stable/24096728. Accessed 21 Apr. 2020

[7] Damian Zine. "Kenya's Ivory Inferno: Does Burning Elephant Tusks Destroy Them?" BBC News, 29 Apr. 2016, www.bbc.com/news/world-africa-34313745. Accessed 13 Nov. 2019

[8] Ivory Stockpiles, "Destroying Elephant Ivory Stockpiles: No Easy Matter." National Geographic Society Newsroom, 2 Aug. 2013, blog.nationalgeographic.org/2013/08/02/destroying-elephant-ivory- stockpiles-no-easy-matter/. Accessed 13 Nov. 2019.

[9] "Kenya Sets Ablaze 105 Tons of Ivory." Nationalgeographic.Com, 30 Apr. 2016, www.nationalgeographic.com/news/2016/04/160430-kenya-record-breaking-ivory-burn/. Accessed 13 Nov. 2019.

[10] Ibid.

[11] Dominic Smith. "Kenya Burns Largest Ever Ivory Stockpile to Highlight Elephants' Fate." The Guardian, The Guardian, 30 Apr. 2016, www.theguardian.com/environment/2016/apr/30/kenya-to-burn- largest-ever-ivory-stockpile-to-highlight-elephants-fate. Accessed 13 Nov. 2019.

[12] "Kenya Sets Ablaze 105 Tons of Ivory." Nationalgeographic.Com, 30 Apr. 2016, www.nationalgeographic.com/news/2016/04/160430-kenya-record-breaking-ivory-burn/. Accessed 13 Nov. 2019.

[13] Alexander, Braczkowski et al. "Reach and Messages of the World's Largest Ivory Burn." Conservation Biology, vol. 32, no. 4, 20 June 2018, pp. 765-773, 10.1111/cobi.13097. Accessed 13 Nov. 2019.

[14] Ivory Stockpiles, "Destroying Elephant Ivory Stockpiles: No Easy Matter." National Geographic Society Newsroom, 2 Aug. 2013, blog.nationalgeographic.org/2013/08/02/destroying-elephant-ivory- stockpiles-no-easy-matter/. Accessed 13 Nov. 2019.

[15] Ibid.

[16] Ibid.

[17] Ibid.

[18] "Kenya Sets Ablaze 105 Tons of Ivory." Nationalgeographic.Com, 30 Apr. 2016, www.nationalgeographic.com/news/2016/04/160430-kenya-record-breaking-ivory-burn/. Accessed 13 Nov. 2019.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] "Historic U.S. Ivory Crush a Call to Global Action." Nationalgeographic.Com, 16 Nov. 2013, www.nationalgeographic.com/news/2013/11/131115-united-states-ivory-crush-ivory- trafficking-philippines-clinton-global-initiative-world/. Accessed 13 Nov. 2019.

[24] Knight, P, Forbes (online); "China Bans Ivory" accessed April 2020 at: https://www.forbes.com/sites/insideasia/2018/01/05/china-bans-ivory-why-2018-is-the-year- of-the-elephant/#7a3d8c881e93; Jan 5, 2018

[25] Parke P; CNN Online; Dumping subway trains into the ocean ... in a good way; accessed April 2020 at https://www.cnn.com/2015/02/26/world/subway-cars-coral-reef/index.html; 26 Feb. 2015