Fly Ash Management Plan
(Handling of Air Pollution Control Residues)
Greater Male Waste-to-Energy Project

1 Generation of Air Pollution Control Residues

As per Employer's Requirements (ERQ) of the envisaged DBO Contract, the Air Pollution Control (APC) system shall consist of a semi-dry or dry system that will generate hazardous residues containing the acid and organic flue gas components and heavy metals in a soluble form which require careful handling. The volume of APC residues depends on the type of absorbent used to clean the flue gases. According to a preliminary mass balance prepared during the feasibility study around 50 kg APC residues per tonne of waste will be generated. In total, approx. 8,500 tonnes are expected to be generated every year if the facility runs at full capacity. According to the European BAT Reference Document for Waste Incineration (BREF) Document that is to be applied, APC residues including the fly ash that is retained by the APC system must not be commingled with the boiler ash and the bottom ash.

APC residues are regarded in all countries that are incinerating waste as hazardous due to their heavy metal content in an easily leachable form. Subject to the absorbent and, of course, the type of waste incinerated, the composition of the APC residues may be characterised as listed in Table 1 (heavy metals highlighted in dark grey).

Table 1: Components of the residues of a semidry/dry APC system[1]

Element	Content in mg/kg
Ca	110,000 – 350,000
K	5,900 – 40,000
Mg	5,000 – 14,000
Na	7,600 – 29,000
Si	36,000 – 120,000
Cl	62,000 – 380,000
S	1,400 – 25,000
Al	12,000 – 83,000
Fe	2,600 – 71,000
As	18 – 530
Ba	51 – 14,000
Cd	140 – 300
Cr	73 - 570
Cu	16 – 1,700
Hg	0.1 – 51
Mn	200 – 900
Mo	9 – 29
Ni	19 – 710
Pb	2,500 – 10,000
Sb	300 – 1,100
V	8 – 62

[1] according to Chandler, Eighmy, Hartlém, Hjelmar, Kosson, Sawell, von der Sloot, Vehlow: Municipal solid waste incinerator residues (1997), cited in Management of APC residues from WtE Plants, ISWA 2008

Zn	7,000 – 20,000

Besides the combustion conditions in the furnace (2 sec, 850°C), the homogeneity of the conditions across the furnace cross section and a sufficient turbulence in the post combustion chamber is an important parameter to control the dioxin and furan contents of the APC residues. Measurements in UK from 2004 revealed concentration between 800 and 1,750 ng TEQ/kg while eluates did not show a significant level above background contamination which was between 0.4 and 2 pg/l[2].

2 Envisaged APC residue treatment and other nations current disposal practices

Because no worldwide methodology or guideline on how to deal with APC residues in an environmentally sound and technically feasible manner has been established, most nations do follow their own approach which again is subject to the local conditions such as availability of disposal sites, national legislation and the costs of the APC residue treatment.

In Germany, APC residues from dry/semi-dry system are usually stored in old salt mines as backfilling material (only if water ingress can be ruled out). Facilities in France with bicarbonate as absorbent apply an extraction of heavy metals at pH 9 and thus try to reuse the bicarbonate (which yet contains chloride) from the so obtained brine. As disposal option for the heavy metals, hazardous waste landfills are used. Dutch facility uses big bags with inlet liners and douses the APC residues during unloading with water to trigger pozzolanic reactions. By this, the APC residues solidify while the inlet liners of the big bags prevent water seepage into the big bags.

In the USA, APC residues are stored mostly in hazardous waste landfills. Some facilities use the bottom ash to stabilise the APC residues (due to pozzolanic effect of bottom ash after dousing with water).

Some Japanese facilities (appr. 30) vitrify both the bottom ash and APC residues, thus obtaining a highly concentrated and salt-rich residue (which is difficult to handle though). Costs for this kind of treatment are significant and can be as high as $500/tonne of residue.

Deliberately, a stabilisation/solidification of the APC residues or any other treatment method was not explicitly prescribed to allow the DBO Contractor to develop a solution that meets the local requirements. Adding cement, for example, can, subject to the absorbent used in the APC system, triple the amount of residues to be landfilled which may be a costly undertaking in the Maldives. Hence, other pozzolanic reaction inducing additives have to be selected if the Contractor opts for such a solution. Space requirements for storing the stabilised bricks while they undergo the transformation was another factor which cannot be ignored. A plant to process around 25 tonnes per day requires 40mx20m, most of the space for storage to allow the bricks to solidify – up to 8 weeks.

[2] Testing of residues from incineration of municipal solid waste, UK Environment Agency, 2004

Whether and to what extent, the DBO Contractor will use the residues after the bottom ash treatment to trigger a pozzolanic reactions, shall be left to the sole discretion of the Contractor which is in line with the general principles of a DBO contract to stimulate the competition of the bidders to present the technically most robust but an economically attractive solution.

Because the Maldives do not have a comprehensive environmental regulatory framework yet, the European standards that according to the BREF Document do require a separate handling of the bottom ash and the APC residues are regarded as the best option to maximise the reuse of the bottom ash and to concentrate the toxic substances within the smallest volume of residues, i.e. the APC residues. Since the BREF Document does not define the landfilling and the treatment of the APC residues and a DBO Contractor may have a preference for the one or other treatment option, it shall be left to the DBO Contractor to develop the solution against the standards that are defined in the ERQ.

During the design review, the Contractor has to provide the full documentation of for the APC residue handling. In the event it does not meet good international industrial practice or does not achieve the desired design standards, the Employer has any right to request modification.

3 Design Build Requirements as per ERQ

To avoid any impact to the environment and to the Contractor's personnel safety, the Contractor's design shall consider the following for conveying and loading APC residues:

- APC residues shall not be mixed with bottom or boiler ash prior to the bottom ash treatment.
- APC residues shall be conveyed in closed conveying systems that end up in storage silos whose exhaust air can be dedusted via a central dedusting system.
- The top of the bag filter housing shall be enclosed and shall be connected to the central dedusting system (while pulling/replacing bag-filter hoses).
- Discharging the APC residues from the silos into water-tight jumbo bags (with inlet) or into the transfer vehicles shall be carried out via dust-tight discharging chutes.
- APC residues shall be treated by either stabilization/solidification or via triggered pozzolanic reaction prior to landfilling to limit the leachability of heavy metals.

The ERQ request the Contractor to design and construct the landfill for the APC residues according to the European Landfill Directive 1999/31/EC and its latest amendment 2018/850/EC. The design of the landfill – i.e. whether a single compartment or different compartments for the APC residues and the remaining bottom ash – shall be subject to the design considerations of the Contractor. In any case, the Contractor shall take account of the following:

- The barrier system shall encompass an artificially completed/reinforced geological barrier (thickness shall be not less than 0.5 m) that can offer an equivalent protection as defined in the European Landfill Directive 1999/31/EC for hazardous wastes. An impermeable artificial liner for at least the compartment that is designated for the APC residues shall be provided. Given that Maldivian soils do not offer a geological barrier having a hydraulic conductivity of less than 10^{-9} m/s and a thickness of more

than 5 m, the artificial geological barrier is the only way to apply to multi-barrier system.

- The compartment, if any, for the residues from the bottom ash processing shall be provided with an artificially completed geological barrier. Its thickness shall not be less than 0.5 m and shall meet the hydraulic resistance requirements for non-hazardous waste as stipulated in the European Landfill Directive.
- The barrier system shall be designed to allow minimizing the leachate generation by dividing the compartments into cells that will accommodate waste subsequently according to the filling plan of the landfill.
- The lower level of the engineered barrier shall be no deeper than 1.5 meters above mean sea level and in accordance with the applicable environmental standards;
- Prior to construction, the Contractor shall prepare a test pad to demonstrate the effectiveness of the proposed engineered barrier.
- In the design of the Contractor, a composite cover system shall be included (see also operational requirements).

For the leachate management, the Contractor shall take into consideration the following:

- The design shall warrant a minimized leachate generation applying means, such as, but not limited to, constructing a shed above the hazardous waste compartment, separating not contaminated water from leachate by installing gate valves, constructing bunds to control the leachate flows, etc.
- The design of the Contractor shall take account of that leachate from different compartments for APC residues and residues from the bottom ash processing are collected and treated so that the leachate discharge standards are met any time. Applying strictest discharge standards is the only way to control the APC residue disposal in the Maldives case.
- The Contractor shall design and build or organize a system for the safe collection, transport and disposal of the LTP concentrate.
- Subject to its design, the Contractor shall re-inject the concentrate after the leachate treatment in the air pollution control system or shall evaporate it. In the latter case, the residues shall be disposed on the landfill so that no accumulation of the highly soluble material is to be concerned.
- Monitoring wells to detect any potentially escaping leachate shall be installed.

4 Requirements during Operation Service Period

Focusing on the APC residues, during landfilling the Contractor shall consider:

- APC revenues shall be disposed safely to landfill meeting the European standards (1999/31/EC) as defined for hazardous waste. Safe disposal means that APC residues shall be unloaded either into water-tight jumbo bags in a semi-solid state (after dousing with water) or shall be stabilized/solidified. Given that APC residues are the only type of hazardous waste, no acceptance tests are needed.
- The Contractor shall dispose of all APC residues and any other residual wastes (i.e. excluding bottom ash for recycling and valuable wastes to be exported for reuse) to the dedicated landfill cells located within the Site, in accordance with the approved

Residual Waste Plan which requests the Contractor to assign the landfill areas for the disposal of the APC residues.

- The method of APC residue disposal shall be as detailed in the Contractor's approved Operation and Maintenance Plan and the Contractor's approved Annual Residual Waste Plan. The Contractor shall arrange all APC disposal as necessary to achieve the most efficient use of the available landfill volume.
- The Contractor shall minimize the generation of leachate by applying control measures including, but not limited to, closing gate valves where appropriate, covering landfill areas that are not needed as working face with impermeable liners, preparing an optimized Residual Waste Plan.
- During the Operation Service Period, the Contractor shall prepare a closure plan that shall including the following:
    - A stability calculation of the envisaged final shape of the landfill body demonstrating its stability considering appropriate friction and slippage coefficients of the materials landfilled and the cover layers applied.
    - A contour layer to smoothen the final shape of the landfill body.
    - A complemental dual cover system for the hazardous APC residues so that in the event one layer fails the other layer can withstand the ingress of water. In the event a mineral layer is applied, the layer shall provide a calculated percolation rate similar to a mineral layer of at least 0.5 m thickness having a permeability coefficient of not greater than $5x10^{-10}$ m/s at a constant water head of 0.3 m. If a geomembrane is used, its thickness shall be not less than 2.0 mm.
    - A leakage control system shall be applied for the dual cover system.
    - A sufficiently dimensioned drainage layer (thickness $\geq$ 0.3 m, permeability coefficient $\geq 5x10^{-3}$ m/s).
    - A recultivation layer incl. a natural vegetal cover (thickness > 0.5 m) that meets the local conditions
- The leakage control system shall be operated after closure of the landfill (sub)cells. Samples shall be taken every quarter and fingerprint analyses shall be carried out.
- Samples from the monitoring wells shall be analyzed regularly (at least once per quarter) for parameters such as PAHs, phenols, cadmium, chromium (hexavalent and total), copper, iron, lead, mercury, nickel, zinc.

Requirements towards the APC residues handling and the components necessary to retain APC residues include:

- The Contractor shall handle and dispose of all APC residues and ensure that processing is conducted in a manner that prevents fugitive emissions and escape of dust.
- Bag filter hoses shall be replaced only if the central dedusting system is operational.
- Unloading the silos shall be carried out using dust-tight unloading chutes only.
- The area around the APC residues silo shall be kept clean at all times and spills shall be dealt with immediately.
- The driver of the APC residues transport vehicle shall be required to use personal protective equipment during loading and unloading to prevent the inhalation of dust and fumes.