

From: [REDACTED]
To: [Cleve Hill Solar Park](#)
Subject: Cleve Hill Solar Park my ref 20018862
Date: 09 September 2019 23:08:45
Attachments: [REDACTED]

Dear Madam or Sir,

Please find attached written summary and report on the additional objections to the Cleve Hill Solar Park development, which I intend to present at the Open Floor Hearing 3, on Tuesday, 10th September 2019.

With regards,

Cleve Hill Case Team
1/18 Eagle Wing
The Planning Inspectorate
Temple Quay House
Temple Quay
Bristol
BS1 6PN

9th September 2019

Ref: 20018862

Cleve Hill Solar Park Development – Battery Storage Systems Objections

Dear Madam or Sir,

I would like to express my objection to the Cleve Hill Solar Park development based on a number of issues not previously presented. The additional main issues which I would like to bring to the attention of the Planning Inspectorate are summarised as follows:

Decommissioning and waste disposal costs for battery storage systems and redundant solar panels

Based on various considerations provided in written submission, it is estimated that the battery storage systems for the proposed CHSP development may be approximately 257,126m³. The current cost for hazardous waste disposal in the UK is about £154 per ton. It is estimated that waste disposal costs for hazardous battery storage units may be in the region of £39,597,404.

The CHSP development submitted planning application suggests that approximately 880,000 solar panels will be installed. Based on conversion factors detailed in IRENA 2016, the weight of the 880,000 solar panels is approximately 17,687tons.

Based on the current costs for hazardous waste disposal in the UK of £154 per ton, waste disposal costs for the solar panels may be in the region of £2,723,915.

Thus, based on limited information provided by CHSP, it is estimated that current waste disposal costs for the battery storage systems and solar panels may be in the region of £42,351,319.

It is my opinion that significant costs will entail in the future during decommissioning of the CHSP development and recommend to the Planning Inspectorate that a minimum financial bond is provided by CHSP in advance of any development, of a minimum of £45million to ensure sufficient funds will be available for decommissioning of the CHSP development. It is also recommended that this financial bond is reviewed annually and increased according to rising costs for hazardous waste disposal.

Human health effects of previous reported exposure model

In my previous objection report I used the ALOHA dispersion modelling tool and considered the case of a 10,000kWh battery storage system catching fire and generating hydrogen fluoride for a duration of 60 minutes, the predicted ambient hydrogen fluoride concentrations exceed the derived domestic property exposure limit by a factor of 2,444 at a distance of 4.5km and a factor of 1,333 at distance of

7.8km and a factor of 55 at a distance of 10km. A derived exposure limit for domestic properties of 0.018ppm was used.

The potential health effects as published by Public Health England are as follows:

- At ambient concentrations of hydrogen fluoride at 44ppm, predicted up to a distance of 4.5km, that at or above this concentration the general population could experience life-threatening health effects or death;
- At ambient concentrations of hydrogen fluoride at 24ppm, predicted up to a distance of 7.8km, that at or above this concentration there may be irreversible or other serious long-lasting effects or impaired ability to escape;
- At ambient concentrations of hydrogen fluoride at 1ppm, predicted up to a distance of 10km, that at or above this concentration the general population could experience notable discomfort.
- Based on the additional information published by Public Health England, I would like to reiterate that the risk to human health in a catastrophic fire event of a 10,000kwh battery storage system is very significant and foreseeable, and in my opinion not acceptable to potentially expose a large number of residents in close vicinity of the proposed development at CHSP.

Based on the foreseeable and significant human health risks and human health effects from the proposed battery storage systems for the Cleve Hill Solar Park, I would like to reiterate and recommended that any such battery storage system should be at least 15km from any population.

Potential environmental effects of Vanadium redox flow batteries

It was brought to my attention that CHSP development may use vanadium redox flow batteries, instead of Lithium Chloride based batteries.

Based on the technical information detailed by Bryans et al., 2018, I have extrapolated these values to the proposed 350MW (350,000kW) CHSP development using 200kW unit equivalents, estimating that about 1,750 of these units would be required. Vanadium redox batteries use sulphuric acid and vanadium.

It can be calculated that approximately 45,500,000 litres (45,500m³) of electrolyte of a 2 Mole sulphuric acid solution is required for the 350MW system. This equals to approximately 4,941,300 litres (4,941m³) of concentrated sulphuric acid.

Using the same approach, it can be calculated that approximately 8,275,540kg (8,275tons) of vanadium is dissolved in the 45,500,000 litres (45,500m³) of electrolyte solution considering 1 Mole vanadium (i.e 181.88g vanadium per litre) for the 350MW system.

Recommendation- Vanadium Redox Flow Batteries

It is recommended to the Planning Inspectorate to consider that vanadium redox flow batteries are unsuitable for the proposed CHSP development due to foreseeable and significant environmental and the site specific constrains.

Leaching potential of damaged solar panels

Damaged solar panels have the potential to leach heavy metals into soil matrix (Bio Intelligence Service, 2011 and Ramos-Ruiz et al., 2017)

It is recommended to the Planning Inspectorate that CHSP development conduct a thorough investigation and assessment in accordance with UK assessment methodology in relation to mitigation measures for damaged solar panels and undertake an environmental risk assessment of the leaching potential of heavy metals from the solar panels. These investigations should consider site specific environmental constraints such as flood risk, shallow ground water and controlled water in close proximity of the solar panel locations.

Decommissioning and waste disposal costs for battery storage systems and redundant solar panels

During the recent Issue specific hearing in relation to the Draft Development Consent Order, the potential costs for decommissioning after an operational life of 40 years of the battery storage systems and solar panels have not been specifically referred to.

Based on very limited information submitted by CHSP development, I have attempted to estimate potential waste disposal costs for battery storage systems and solar panels.

Based on the drawing 'Proposed development layout, Figure 1.2, ref:2238-REP-053, dated 29/05/2018, I have estimated the surface area allocated for the battery storage system to be approximately 70,038m². I also make reference that CHSP development refer to a number of 7,440 units in their application, albeit do not provide dimensions of these battery storage units. Due to the lack of this information, it is difficult to provide the most appropriate estimate.

However, I used the assumption that the proposed battery storage units are equivalent to 20-foot containers. Using this assumption, the footprint of 7,440 units would be 107,136m², exceeding the allocated surface area. However, it became apparent during the issue specific hearing on DCO that CHSP development proposed to create a bund of a height of 5.37m. Generally, bunds are calculated considering a factor of 110%. Extrapolating this allowance to the potential height of the battery storage systems within the bund, a value of 4.881m is calculated.

The assumption has been made that the 20-foot equivalent battery storage systems are stacked two at a time. Extrapolation of this assumption is that the surface area required for the 7,440 battery storage systems is 53,568m². Using these assumptions, it is apparent that these now fit into the allocated area of 70,038m².

Based on these considerations, it is estimated that the battery storage systems for the proposed CHSP development may be approximately 257,126m³.

Lithium batteries are considered hazardous waste in the UK due to the potential of leaching heavy metals.

The current cost for hazardous waste disposal in the UK is about £154 per ton. Assuming a density of 1, it is estimated that waste disposal costs for hazardous battery storage units may be in the region of £39,597,404.

Redundant Solar Panels

In addition to the waste disposal costs for the battery storage systems, the waste disposal costs for the solar panels have to be considered. Solar Panels are also considered hazardous waste in the UK in the case no recycling facilities are available due to potential leaching of heavy metals such as cadmium, arsenic, hexavalent chromium, copper and selenium, subject to actual type of solar panel selected.

The CHSP development submitted planning application suggests that approximately 880,000 solar panels will be installed. Based on conversion factors detailed in IRENA 2016, the weight of the 880,000 solar panels is approximately 17,687tons.

Based on the current costs for hazardous waste disposal in the UK of £154 per ton, waste disposal costs for the solar panels may be in the region of £2,723,915.

Thus, based on limited information provided by CHSP, it is estimated that current waste disposal costs for the battery storage systems and solar panels is in the region of £42,351,319. These costs exclude any labour, machinery and transport for any decommissioning works.

It is my opinion that significant costs will entail in the future during decommissioning of the CHSP development and recommend to the Planning Inspectorate that a minimum financial bond is provided by CHSP in advance of any development, of a minimum of £45million to ensure sufficient funds will be available for decommissioning of the CHSP development. It is also recommended that this financial bond is reviewed annually and increased according to rising costs for hazardous waste disposal.

Human health effects of previous reported exposure model

During the open floor hearing 2, on 22nd July 2019, I presented my objections to the CHSP development due to insufficient human health risk assessments and detailed scenarios of potential exposure of the population, in an event of a catastrophic fire event, to toxic hydrogen fluoride concentrations. In this report I derived an exposure limit for domestic properties for hydrogen fluoride and the exceeding of the derived exposure limit.

I have since carried out further research and would like to bring to the Planning Inspectorate's attention the information published by Public Health England, presented in Appendix 1. The main concerns are the potential human health effects as detailed and summarised in table 'acute exposure guideline levels'. Page 9 of this document.

In my previous objection report I used the ALOHA dispersion modelling tool and considered the case of a 10,000kWh battery storage system catching fire and generating hydrogen fluoride for a duration of 60 minutes, the predicted ambient hydrogen fluoride concentrations exceed the derived domestic property exposure limit by a factor of 2,444 at a distance of 4.5km and a factor of 1,333 at distance of 7.8km and a factor of 55 at a distance of 10km. A derived exposure limit for domestic properties of 0.018ppm was used.

The potential health effects as published by Public Health England are as follows:

- At ambient concentrations of hydrogen fluoride at 44ppm, predicted up to a distance of 4.5km, that at or above this concentration the general population could experience life-threatening health effects or death;
- At ambient concentrations of hydrogen fluoride at 24ppm, predicted up to a distance of 7.8km, that at or above this concentration there may be irreversible or other serious long-lasting effects or impaired ability to escape;
- At ambient concentrations of hydrogen fluoride at 1ppm, predicted up to a distance of 10km, that at or above this concentration the general population could experience notable discomfort.

Based on the additional information published by Public Health England, I would like to reiterate that the risk to human health in a catastrophic fire event of a 10,000kwh battery storage system is very

significant and foreseeable, and in my opinion not acceptable to potentially expose a large number of residents in close vicinity of the proposed development at CHSP.

I feel that the Applicant's response (document, dated 30/08/2019) provided to the Planning Inspectorate to my objection is completely insufficient by stating that 'locating battery storage at least 15 km from residential properties is not considered to be practicable in the UK'.

Potential environmental effects of Vanadium redox flow batteries

It was brought to my attention that CHSP development have recently formed a business arrangement with a manufacturer of vanadium redox flow batteries. As CHSP development have as yet not specified which type of battery storage system will be used, there is a possibility that vanadium redox flow batteries may be used.

I have researched this type of battery storage system, and would like to bring to the attention of the Planning Inspectorate, that vanadium redox flow batteries may have significant environmental risks.

Vanadium redox flow batteries are reported to be less of a fire risk compared to other battery systems such as sodium sulphur and lithium ion batteries.

I have consulted a technical paper by Bryans et al., 2018, in relation to characterisation of a 200kW/400kWh vanadium redox flow battery.

I have limited presentation of the operation of the vanadium redox flow battery to the bare minimum, but to emphasize that this type of battery uses vanadium as the carrier of the electrical charge and using sulphuric acid as electrolyte, which is pumped through the cell component.

In the example presented by Bryans et al., 2018, of testing a 200 kW vanadium redox flow battery, for the operation of this size of battery, a total electrolyte volume of 26,000L was used and was composed of 1.6Mole vanadium species in concentrated (2Mole) sulphuric acid.

Extrapolation of Vanadium Redox Flow Batteries for CHSP development

Based on the technical information detailed by Bryans et al., 2018, I have extrapolated these values to the proposed 350MW (350,000kW) CHSP development using 200kW unit equivalents, estimating that about 1,750 of these units would be required.

Sulphuric acid extrapolation

It can be calculated that approximately 45,500,000 litres (45,500m³) of electrolyte of a 2 Mole sulphuric acid solution is required for the 350MW system.

The specific density of concentrated sulphuric acid is 18.4 Moles per litre. Thus, for the operation of vanadium redox flow batteries for the CHSP development for the storage of 350MW (350,000kW) of energy, it is calculated that approximately 4,941,300 litres (4,941m³) of concentrated sulphuric acid is required. Beside potential environmental risks, which will be further detailed below, I would like to stress that are considerable additional safety concern for the transport and transfer of these quantities to the site and at the site.

Vanadium extrapolation

Using the same approach, it can be calculated that approximately 8,275,540kg (8,275tons) of vanadium is dissolved in the 45,500,000 litres (45,500m³) of electrolyte solution considering 1 Mole vanadium (i.e 181.88g vanadium per litre) for the 350MW system.

Site Specific Risk Assessment

For the assessment of potential accidental release of the electrolyte of the vanadium redox flow battery systems the following additional site specific environmental settings have to be considered. These are summarised as follows:

- The CHSP development is located in a known flood risk zone;
- The water table is very shallow (i.e. approximately 1.4m below apparent ground level)
- There is an extensive drainage system beneath the top soil/sub base layer estimated to be 0.6m below apparent ground level;
- The soils at the site consist of clay and calciferous clay soils and sandy clay;
- There are numerous drainage ditches across the site and in close proximity of the proposed battery storage area which discharge into the main marshland basin.

Potential Environmental Release

Considering the volumes and quantities of electrolyte and vanadium required to operate vanadium redox flow batteries, there are considerable environmental risks inherent to a vanadium redox flow battery system, in the case of an accidental release. The CHSP development is proposed to be operational for at least 40 years and over this period of time an accidental release has to be considered.

A potential accidental release scenario is envisaged using a 200kW vanadium redox flow battery system as an example.

As detailed above, a 200kW vanadium redox flow battery as described by Bryan et al., 2018, uses 26,000 litre of electrolyte constituting a 2 Mole sulphuric acid solution and 1 Mole vanadium. Thus, accidental release of the entire electrolyte solution from one 200kW system would release a quantity of vanadium of 4,728,880g.

Infiltration and hydraulic conductivity

Infiltration rates and hydraulic conductivity of the top soils and subbase soils at the CHSP site are currently not known. However, Nkalai, 1983 in his theses examined similar types of sandy clay and calciferous soils and reported hydraulic conductivities ranging between 2.18 to 22.75 mm/hr.

Thus, infiltration of the very acidic electrolyte from an accidental release could reach the shallow ground water level (1.4 m below apparent ground level) of between 2 days to 26 days and could reach the field drainage system within 1 day to 11 days.

Absorption, desorption, soil buffer capacity and cation exchanges within soils matrix are complex and would require further assessment. However, it can be predicted that a significant impact to soils within the spill area and the shallow ground water and the water contained within the drainage ditch will occur from the very acidic electrolyte. The water volume within the receiving ditch is estimated to be approximately 285m³ (based on site observations made in May 2019). It can be predicted that the pH of the entire volume of water will become extremely acidic and polluted with vanadium.

Environmental Standards Vanadium

The UK Environmental Quality Standard for vanadium in Controlled Waters ranges between 20 to 60 µg/L (dependent on the presence of CaCO₃).

Thus, infiltration of a significant quantity of very acidic electrolyte and a significant fraction of the 4,728,800g of vanadium contained within the electrolyte can be predicted to enter the water within the drainage ditch and shallow ground water and will predictably exceed the EQS for vanadium in Controlled Waters.

Further investigations, assessments and modelling would be required to derive calculated impact values.

Conclusions – Vanadium Redox Flow Battery Systems

However, considering the potential large volumes and quantities of concentrated sulphuric acid and vanadium required to operate vanadium redox batteries for the 350MW CHSP development, it can be stated that this type of battery system poses potentially foreseeable and significant environmental risks. In addition, considering the known flood risk of the area, the shallow ground water table at the site and the extensive field drainage systems across the proposed development area all these site-specific criteria contribute to an increase of the environmental risk.

Recommendations – Vanadium Redox Flow Battery Systems

It is recommended to the Planning Inspectorate to consider that vanadium redox flow batteries are unsuitable for the proposed CHSP development due to foreseeable and significant environmental and the site specific constraints.

Leaching potential of damaged solar panels.

Damaged solar panels have the potential to leach heavy metals into soil matrix (bio Intelligence Service, 2011 and Ramos-Ruiz et al., 2017). I have as yet not noted any clear statement from CHSP

development in relation to any mitigation measures in the case of accidental damage of any of the solar panels proposed for the site.

CHSP proposes to install approximately 880,000 solar panels and operate for a period of 40 years. The assumption has to be made that the operational period, accidental damage or natural events such as hail storms and tornadoes damaging these panels may occur. Significant damage to solar panels by natural events occurred in California in 2015 and Puerto Rico in 2017.

It is recommended to the Planning Inspectorate that CHSP development conduct a thorough investigation and assessment in accordance with UK assessment methodology in relation to mitigation measures for damaged solar panels and undertake an environmental risk assessment of the leaching potential of heavy metals from the solar panels. These investigations should consider site specific environmental constraints such as flood risk, shallow ground water and controlled water in close proximity of the solar panel locations.

This report was prepared by Bruno Erasin, BSc, PhD.

Appendices

Appendix I – Public Health England. 2017. Hydrogen Fluoride and Hydrofluoric Acid (HF) – Incident Management

References

Human Health Risks

Public Health England. 2017. Hydrogen Fluoride and Hydrofluoric Acid (HF) – Incident Management

Vanadium Redox Flow Batteries

Declan Bryans, Veronique Amstutz, Hubert H. Girault and Lenoard E.A. Berlouis. Characterisation of a 200kW/kWh Vanadium Redox Flow Battery. Batteries, 2018, 4, 54;

Metal Pollution/Environmental Risks

David M. T. Nkalai, 1983. Field Water holding capacity and hydraulic conductivity of a calcareous and a non-calcareous soil.

Environmental Agency, including Environmental Agency R&D Publication 20 (2006) “Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination”.

Environment Agency Groundwater Protection: Policy and Practice, Part 3 – tools (GP3). (August 2013, version 1.1).

The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010.

Solar Panel Leaching Potential

Adriana Ramos-Ruiz, Jean V Wilkening, James A Field and Reyes Sierra-Alvarez. J Hazard Mater, 2017. 336: 57-64.

Bio Intelligence Service. Study on Photovoltaic Panels Supplementing The Impact Assessment For A Recast of the WEEE Directive. European Commission DG ENV, A project under the Framework contract ENV.G.4/FRA/2007/0067. Final Report, 14 April 2011.



Hydrogen Fluoride and Hydrofluoric Acid (HF)

Incident Management

Key Points

Fire

- strong acid when pure, reacts violently with bases and is corrosive; reacts violently with any compounds causing fire and explosion hazard
- attacks metals, concrete, glass, some forms of plastic, rubber and coatings
- in case of fire involving hydrogen fluoride/hydrofluoric acid use fine water spray. Wear chemical protective clothing with liquid-tight connections for whole body in combination with breathing apparatus

Health

- hydrogen fluoride causes severe and deep burns which are extremely painful and difficult to heal
- ingestion may cause burning of the mouth and throat with retrosternal and abdominal pain; there is often hypersalivation, vomiting, haematemesis and hypotension
- irritation of eyes and nose with sore throat, cough, chest tightness, headache, ataxia, confusion, dyspnoea and stridor may follow inhalation
- contact with the eyes may cause conjunctivitis, conjunctival oedema, corneal epithelial coagulation and necrosis
- exposure to hydrogen fluoride may cause systemic effects including cardiotoxicity, secondary to hypocalcaemia, hypomagnesaemia and metabolic acidosis



Environment

- avoid release to the environment; inform the Environment Agency where appropriate

Hazard Identification

Standard (UK) dangerous goods emergency action codes

Hydrogen fluoride, anhydrous

UN		1052	Hydrogen fluoride, anhydrous	
EAC		2XE	Use fine water spray. Wear chemical protective clothing with liquid-tight connections for whole body in combination with breathing apparatus*. Spillages and decontamination run-off should be prevented from entering drains and watercourses. There may be a public safety hazard outside the immediate area of the incident [†]	
APP		B	Gas-tight chemical protective suit with breathing apparatus [‡]	
Hazards	Class	8	Corrosive substance	
	Sub-risks	6.1	Toxic substance	
HIN		886	Highly corrosive substance, toxic	

UN – United Nations number, EAC – emergency action code, APP – additional personal protection, HIN – hazard identification number

* Chemical protective clothing with liquid-tight connections for whole body (Type 3) conforming to relevant standards such as BS 8428 or EN 14605, in combination with breathing apparatus BS EN 137



[†] People should stay indoors with windows and doors closed, ignition sources should be eliminated and ventilation stopped. Non-essential personnel should move at least 250 m away from the incident

[‡] Normal fire kit in combination with gas-tight chemical protective clothing conforming to BS EN 943 part 2

Reference

Dangerous Goods Emergency Action Code List, National Chemical Emergency Centre (NCEC) Part of Ricardo-AEA. The Stationery Office, 2017.

Hydrofluoric acid with more than 60% hydrogen fluoride, packing group I

UN		1790	Hydrofluoric acid with more than 60% hydrogen fluoride, packing group I	
EAC		2W	Use fine water spray. Wear chemical protective clothing with liquid-tight connections for whole body in combination with breathing apparatus*. Spillages and decontamination run-off should be prevented from entering drains and surface and ground waters. Substance can be violently or explosively reactive	
APP		B	Gas-tight chemical protective suit with breathing apparatus [†]	
Hazards	Class	8	Corrosive substance	
	Sub-risks	6.1	Toxic substance	
HIN		886	Highly corrosive substance, toxic	



UN – United Nations number, EAC – emergency action code, APP – additional personal protection, HIN – hazard identification number

* Chemical protective clothing with liquid tight connections for whole body (type 3) conforming to the relevant standards such as BS 8428 or EN 14605, in combination with breathing apparatus BS EN 137

Reference

Dangerous Goods Emergency Action Code List, National Chemical Emergency Centre (NCEC) Part of Ricardo-AEA. The Stationery Office, 2017.

Hydrofluoric acid with more than 60% hydrogen fluoride, packing group II

UN		1790	Hydrofluoric acid with more than 60% hydrogen fluoride, packing group II	
EAC		2X	Use fine water spray. Wear chemical protective clothing with liquid-tight connections for whole body in combination with breathing apparatus*. Spillages and decontamination run-off should be prevented from entering drains and watercourses	
APP		—	—	
Hazards	Class	8	Corrosive substance	
	Sub-risks	6.1	Toxic substance	
HIN		86	Corrosive or slightly corrosive substance, toxic	




UN – United Nations number, EAC – emergency action code, APP – additional personal protection, HIN – hazard identification number

* Chemical protective clothing with liquid-tight connections for whole body (type 3) conforming to the relevant standards such as BS 8428 or EN 14605, in combination with breathing apparatus BS EN 137

Reference

Dangerous Goods Emergency Action Code List, National Chemical Emergency Centre (NCEC) Part of Ricardo-AEA. The Stationery Office, 2017.

Classification, labelling and packaging (CLP)***Hydrofluoric acid ... %**

Hazard class and category	Acute Tox. 2	Acute toxicity, category 2 (ingestion, inhalation)	
	Acute Tox. 1	Acute toxicity, category 1 (skin contact)	
	Skin Corr. 1A	Skin corrosion, category 1A	
Hazard statement	H300	Fatal if swallowed	
	H310	Fatal in contact with skin	
	H314	Causes severe skin burns and eye damage	
	H330	Fatal if inhaled	
Signal words	Danger		

* Implemented in the EU on 20 January 2009




Reference

European Commission. Harmonised classification – Annexe VI to Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures. <http://echa.europa.eu/information-on-chemicals/cl-inventory-database> (accessed 08/2017).

Specific concentration limits

Concentration	Hazard class and category	Hazard statement
$1\% \leq C < 7\%$	Skin Corr. 1B	H314
$C \geq 7\%$	Skin Corr. 1A	H314
$0,1\% \leq C < 1\%$	Eye Irrit. 2	H319
<p>Reference</p> <p>European Commission. Harmonised classification – Annexe VI to Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures. http://echa.europa.eu/information-on-chemicals/cl-inventory-database (accessed 08/2017).</p>		

Hydrogen fluoride

Hazard class and category	Acute Tox. 2	Acute toxicity, category 2 (ingestion, inhalation)	
	Acute Tox. 1	Acute toxicity, category 1 (skin contact)	
	Skin Corr. 1A	Skin corrosion, category 1A	
Hazard statement	H300	Fatal if swallowed	
	H310	Fatal in contact with skin	
	H314	Causes severe skin burns and eye damage	
	H330	Fatal if inhaled	
Signal words	Danger		

* Implemented in the EU on 20 January 2009

Reference

European Commission. Harmonised classification – Annexe VI to Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures. <http://echa.europa.eu/information-on-chemicals/cl-inventory-database> (accessed 08/2017).

Physicochemical Properties

CAS number	7664-39-3
Molecular weight	20.0
Chemical formula	HF
Common synonyms	Hydrofluoric acid, anhydrous hydrofluoric acid
State at room temperature	Colourless gas or colourless fuming liquid
Volatility	Vapour pressure = 760 mm Hg at 20°C
Relative density Vapour density	(water =1) 1.0 (liquid at 4 °C) 1.27 at 34°C (air = 1)
Flammability	Not combustible
Lower explosive limit	-
Upper explosive limit	-
Water solubility	Soluble in water
Reactivity	Strong acid reacts violently with bases and is corrosive. Reacts violently with many compounds causing fire and explosion hazard. Attacks metals, concrete, glass, some forms of plastic, rubber and coatings
Reaction or degradation products	May create irritating and corrosives fumes of fluorides when heated or in combination with steam or water
Odour	Strong irritating odour
Structure	$H - F$

References

Hazardous Substances Data Bank. Hydrogen Fluoride HSDB No. 546 (last revision date 06/03/2008) US National Library of Medicine: Bethesda MD. <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB> (accessed 08/2017)

Hydrogen Fluoride (HAZARTEXT™ Hazard Management). In Klasco RK (Ed): TOMES® System, Truven Healthcare Analytics Inc, Greenwood Village CO, US. RightAnswer.com Inc, Midland MI, US. <http://www.rightanswerknowledge.com> (accessed 08/2017).

International Programme on Chemical Safety. International Chemical Safety Card entry for Hydrogen Fluoride. ICSC 0283, 2000. World Health Organization: Geneva.

Reported Effect Levels from Authoritative Sources

Exposure by skin contact

%	Signs and symptoms	Reference
>2	Can cause burns	a
<20	Delayed onset of potentially severe burns (up to 24 hours)	b
20-50	Symptoms in up to 8 hours	a
>20	Systemic effects may develop	b
>40	Rapid onset of effects, immediate pain and skin damage	b
50	Immediate symptoms	a
70	Death by cardiac arrest has been reported	b
<p>These values give an indication of levels of exposure that can cause adverse effects. They are not health protective standards or guideline values</p> <p>References</p> <p>a TOXBASE. Hydrofluoric acid, 2012. http://www.toxbase.org (accessed 08/2017).</p> <p>b International Programme on Chemical Safety. Poisons Information Monograph 268: Hydrogen fluoride, 1995. World Health Organization: Geneva.</p>		

Exposure by inhalation (see note)

ppm	mg/m ³	Signs and symptoms	Reference
0.5-4.5	0.32-2.9	Very mild eye irritation	a
30-50	19.4-32.3	Mild eye irritation	a
100	64.5	Marked irritation	a
<p>Values relate to fluorine which forms hydrofluoric acid in contact with the moisture on eyes and skin</p> <p>These values give an indication of levels of exposure that can cause adverse effects. They are not health protective standards or guideline values</p> <p>References</p> <p>a Agency for Toxic Substances and Disease Registry (ATSDR). 2003. Toxicological profile for Fluorides, Hydrogen Fluoride, and Fluorine. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.</p>			

Published Emergency Response Guidelines

Emergency response planning guideline (ERPG) values

	Listed value (ppm)	Calculated value (mg/m ³)
ERPG-1*	2 ⁽¹⁾	1.64
ERPG-2 [†]	20	16.4
ERPG-3 [‡]	50	41
	10-minute values (ppm) ⁽²⁾	Calculated value (mg/m ³)
ERPG-1*	2	1.64
ERPG-2 [†]	50	41
ERPG-3 [‡]	170	139

* Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour

[†] Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action

[‡] Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects

(1) Odour should be detectable near ERPG-1

(2) 10 minute ERPG values were published in an addendum in 1999

Reference
American Industrial Hygiene Association (AIHA). 2016 Emergency Response Planning Guideline Values.
<https://www.aiha.org/get-involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Documents/2015%20ERPG%20Levels.pdf>
(accessed 08/2017).

Acute exposure guideline levels (AEGLs)

	ppm				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	1	1	1	1	1
AEGL-2 [†]	95	34	24	12	12
AEGL-3 [‡]	170	62	44	22	22

* Level of the chemical in air at or above which the general population could experience notable discomfort

[†] Level of the chemical in air at or above which there may be irreversible or other serious long-lasting effects or impaired ability to escape

[‡] Level of the chemical in air at or above which the general population could experience life-threatening health effects or death

Reference
US Environmental Protection Agency. Acute Exposure Guideline Levels. <http://www.epa.gov/oppt/aegl/pubs/chemlist.htm>
(accessed 08/2017).

Exposure Standards, Guidelines or Regulations

Occupational standards

Hydrogen fluoride (as F)

	LTEL (8-hour reference period)		STEL (15-min reference period)	
	ppm	mg/m ³	ppm	mg/m ³
WEL	1.8	1.5	3	2.5
WEL – workplace exposure limit, LTEL – long-term exposure limit, STEL – short-term exposure limit				
Reference				
Health and Safety Executive (HSE). EH40/2005 Workplace Exposure Limits, 2 nd Edition, 2011.				

Public health guidelines

Drinking water standard WHO guideline value	No values specified
Air quality guideline	No guideline values specified
Soil guideline values and health criteria values	No guideline values specified

Health Effects

Major route of exposure

- ingestion, inhalation, dermal or eye contact

Immediate signs or symptoms of acute exposure

Route	Signs and symptoms
Inhalation	Irritation of eyes and nose with sore throat, cough, chest tightness, headache, ataxia and confusion. Dyspnoea and stridor due to laryngeal oedema may follow. Haemorrhagic pulmonary oedema with increasing breathlessness, wheeze, hypoxia and cyanosis may take up to 36 hours to develop
Ingestion	Burning of the mouth and throat with retrosternal and abdominal pain. The larynx may also be affected causing oedema, airway obstruction and difficulty in clearing bronchial secretions. There is often hypersalivation, vomiting, haematemesis and hypotension. Oesophageal or gastric perforation may occur
Dermal	Severe and deep burns which are extremely painful and difficult to heal. Pain may appear to be disproportionate to physical findings. There may be blue-grey discoloration of the skin in severe cases
Ocular	Conjunctivitis, conjunctival oedema, corneal epithelial coagulation and necrosis
Systemic features	Hypocalcaemia, hypomagnesaemia and metabolic acidosis. Hyperkalaemia is also common. Myoclonus, tetany, convulsions, CNS depression, cardiac conduction disturbances and arrhythmias (prolonged QT interval, ventricular tachycardia and ventricular fibrillation) may occur secondary to hypocalcaemia and other electrolyte disturbances
Reference TOXBASE. Hydrofluoric acid, 08/2012. http://www.toxbase.org (accessed 08/2017) TOXBASE. Hydrofluoric acid – features and management, 02/2012 http://www.toxbase.org (accessed 08/2017)	

Decontamination at the Scene

Summary

The approach used for decontamination at the scene will depend upon the incident, location of the casualties and the chemicals involved. Therefore, a risk assessment should be conducted to decide on the most appropriate method of decontamination.

Hydrogen fluoride is a highly corrosive substance. Burns following exposure to lower concentrations may be delayed for up to 24 hours. If exposure to hydrogen fluoride is known to have taken place, decontamination should still be carried out even in the absence of symptoms. Therefore, following disrobe, improvised wet decontamination should be considered (see below for details).

People who are processed through improvised decontamination should subsequently be moved to a safe location, triaged and subject to health and scientific advice. Based on the outcome of the assessment, they may require further decontamination.

Emergency services and public health professionals can obtain further advice from Public Health England (Centre for Radiation, Chemical and Environmental Hazards) using the 24-hour chemical hotline number: 0344 892 0555.

Disrobe

The disrobe process is highly effective at reducing exposure to HAZMAT/CBRN material when performed within 15 minutes of exposure.

Therefore, disrobe must be considered the primary action following evacuation from a contaminated area.

Where possible, disrobe at the scene should be conducted by the casualty themselves and should be systematic to avoid transferring any contamination from clothing to the skin. Consideration should be given to ensuring the welfare and dignity of casualties as far as possible.

Improvised decontamination

Improvised decontamination is an immediate method of decontamination prior to the use of specialised resources. This should be performed on all contaminated casualties, unless medical advice is received to the contrary. Improvised dry decontamination should be considered for an incident involving chemicals **unless the agent appears to be corrosive or caustic**.

Improvised dry decontamination

- any available dry absorbent material can be used such as kitchen towel, paper tissues (eg blue roll) and clean cloth

- exposed skin surfaces should be blotted and rubbed, starting with the face, head and neck and moving down and away from the body
- rubbing and blotting should not be too aggressive, or it could drive contamination further into the skin
- all waste material arising from decontamination should be left in situ, and ideally bagged, for disposal at a later stage

Improvised wet decontamination

- water should only be used for decontamination where casualty signs and symptoms are consistent with exposure to caustic or corrosive substances such as acids or alkalis
- wet decontamination may be performed using any available source of water such as taps, showers, fixed installation hose-reels and sprinklers
- when using water, it is important to try and limit the duration of decontamination to between 45 and 90 seconds and, ideally, to use a washing aid such as cloth or sponge
- improvised decontamination should not involve overly aggressive methods to remove contamination as this could drive the contamination further into the skin
- where appropriate, seek professional advice on how to dispose of contaminated water and prevent run-off going into the water system

Additional notes

- following improvised decontamination, remain cautious and observe for signs and symptoms in the decontaminated person and in unprotected staff
- if water is used to decontaminate casualties this may be contaminated, and therefore hazardous, and a potential source of further contamination spread
- all materials (paper tissues etc) used in this process may also be contaminated and, where possible, should not be used on new casualties
- the risk from hypothermia should be considered when disrobe and any form of wet decontamination is carried out
- people who are contaminated should not eat, drink or smoke before or during the decontamination process and should avoid touching their face
- consideration should be given to ensuring the welfare and dignity of casualties as far as possible. Immediately after decontamination the opportunity should be provided to dry and dress in clean robes/clothes

Interim wet decontamination

Interim decontamination is the use of standard fire and rescue service (FRS) equipment to provide a planned and structured decontamination process prior to the availability of purpose-designed decontamination equipment.

Decontamination at the scene references

National Ambulance Resilience Unit. Joint Emergency Services Interoperability Programme (JESIP). Initial operational response to a CBRN incident. Version 1.0, September 2013.

NHS England. Emergency Preparedness, Resilience and Response (EPRR). Chemical incidents: planning for the management of self-presenting patients in healthcare settings. April 2015.

Clinical Decontamination and First Aid

Clinical decontamination is the process where trained healthcare professionals using purpose-designed decontamination equipment treat contaminated people individually.

Detailed information on clinical management can be found on TOXBASE – www.toxbase.org.

Important note

- if the patient has not been decontaminated following surface contamination, secondary carers must wear appropriate NHS PPE for chemical exposure to avoid contaminating themselves. The area should be well ventilated
- **decontamination is the immediate priority if the patient is responsive. This should take precedence over transfer to medical facilities, though an ambulance should be requested while decontamination is being undertaken**

Clinical decontamination following surface contamination

- **do not delay decontamination if the patient is responsive**
- **remove contaminated clothing**
- **irrigate the contaminated area with copious amounts of water as soon as possible for at least 1 minute**

Dermal exposure

For detailed clinical management advice on the use of calcium gluconate see TOXBASE – www.toxbase.org

- following decontamination apply calcium gluconate gel repeatedly to the burn. For burns to the hand the use of a surgical glove containing calcium gluconate may be effective at reducing pain
- note if calcium gluconate gel is not available continue to flush with water until it becomes available
- if skin contamination is extensive and clothing affected, be aware of the possibility of inhalation injury
- other supportive measures as indicated by the patient's clinical condition

Ocular exposure

- remove contact lenses if necessary and immediately irrigate the affected eye thoroughly for at **least 30 mins** with water or 0.9% saline
- the evidence for the efficacy of calcium gluconate following ocular exposure is lacking and it may be toxic to the conjunctiva

- repeated installation of local anaesthetics (e.g. amethocaine) may reduce discomfort and help more thorough decontamination. An anaesthetised eye should be covered to protect from traumatic injury
- patients with corneal damage, those who have been exposed to strong acids or alkalis and those whose symptoms do not resolve rapidly should be discussed **urgently** with an ophthalmologist
- other supportive measures as indicated by the patient's clinical condition

Inhalation

- remove from exposure and give oxygen
- maintain a clear airway and ensure adequate ventilation
- urgent assessment of the airway is required
- in severely affected patients, especially those with tachypnoea, stridor or upper airway damage, critical care input is essential with urgent assessment of the airway. A supraglottic-epiglottic burn with erythema and oedema is usually a sign that further oedema will occur that may lead to airway obstruction
- children are at increased risk of airway obstruction
- monitor cardiac rhythm and perform a 12-lead ECG in all patient who require assessment
- other supportive measures as indicated by the patient's clinical condition

Ingestion

- **maintain airway and establish haemodynamic stability**
- gut decontamination is contra-indicated
- **do not give neutralising chemicals** as heat produced during neutralisation reactions may increase injury
- maintain a clear airway and ensure adequate ventilation
- in severely affected patients, especially those with tachypnoea, stridor or upper airway damage, critical care input is essential with urgent assessment of the airway. A supraglottic-epiglottic burn with erythema and oedema is usually a sign that further oedema will occur that may lead to airway obstruction
- children are at increased risk of airway obstruction
- monitor cardiac rhythm and perform a 12-lead ECG in all patient who require assessment
- other supportive measures as indicated by the patient's clinical condition

Antidotes

Further information on the use of calcium gluconate gel is available on TOXBASE.

Health effects and decontamination references

- TOXBASE <http://www.toxbase.org> (accessed 08/2017)
- TOXBASE Hydrofluoric acid – features and management, 02/2012
- TOXBASE Emergency treatment prior to transfer to hospital, 2012

This document from the PHE Centre for Radiation, Chemical and Environmental Hazards reflects understanding and evaluation of the current scientific evidence as presented and referenced here.

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For queries relating to this document, please contact chemcompendium@phe.gov.uk

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