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environmental consultants

Project			
	Supplemental report to the NIS for a proposed Resource Recovery Centre and associated works at Ringaskiddy, Co. Cork		
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1. Introduction

During the oral hearing for the Strategic Infrastructure Development application for a Resource Recovery Centre at Ringaskiddy, Co. Cork, supplemental information was requested by Dr. Jervis Good of the National Parks and Wildlife Service (NPWS, Department of the Arts, Heritage and the Gaeltacht) in relation to possible impacts from engineered nanoparticles. The NPWS submission, (which is attached as **Appendix 1** of this report) recommended that a review of the scientific literature on effects of engineered nanoparticles likely to originate from the proposed waste to energy facility (incinerator) is undertaken, and an assessment of their potential effects on Cork Harbour SPA be included as a supplement to the Natura Impact Statement (NIS).

There are two possible pathways by which engineered nanoparticles, from the waste to energy facility (incinerator), could enter the environment and have a potential impact on a Natura 2000 site. One possible pathway is via emissions to air from the stack. The other possible pathway is via the flue gas cleaning residues if there was a spillage during transport or disposal.

This supplemental report to the NIS is structured as follows;

Section 1 Introduction

Section 2 Literature review of the potential biological/ecological impacts from engineered nanoparticles

Section 3 reviews the potential for such particles to be generated by waste-to-energy facilities

Section 4 looks at the potential risk related to transport of residues

Section 5 provides a conclusion on the potential impact on Natura 2000 sites.

Section 6 Reference list

2. Literature review - Potential biological and ecological impacts from engineered nanoparticles.

Nanoparticles (NPs) are in the 1-nano-metre (nm) to 100-nm size range. Nanoparticles can be composed of many different base materials (carbon, silicon and metals, such as gold, cadmium and selenium) and they have different shapes. Nanoparticles in the environment may be either engineered nanoparticles or nanoparticles from a range of natural or combustion sources. New engineered nanoparticles are different to naturally occurring nanoparticles because they are being fabricated from the "bottom up". Nanoparticle properties differ compared with those of the parent compounds because about 40–50% of the atoms in nanoparticles (NPs) are on the surface, resulting in greater reactivity and potentially will have different biological effects to naturally occurring nanoparticles. The surface properties and the very small size of NPs provide surfaces that may bind and transport toxic chemical pollutants, as well as possibly being toxic in their own right by generating reactive radicals (Farré et al, 2009).

While nanoparticles occur naturally in the environment, the use of engineered nanoparticles has seen a recent spike and use is likely to increase significantly in the future. Metal-based nanoparticles such as silver (Ag) and titanium dioxide (TiO_2) are widely used in industrial and household applications. Because of the increasing use of such engineered nanoparticles and their release into the natural environment, NPs are likely to have a widespread geographic distribution (Dong-Ha Nam, 2014).

2.1 Possible ecosystem impacts

Recent efforts to characterize the toxicity of engineered nanoparticles have focused on the environmental implications, including exploration of toxicity to organisms (Walser et al, 2012). Concern has been expressed about the possible ecological impacts from the accumulation and aggregation of NPs in the aquatic environment, mainly in bottom sediments (Farré et al. 2009). Concern has been also expressed about the impact of such nanoparticles on the functioning of ecosystems. For example Andreia et al, (2016) found that release of nanosilver (nAg) in aquatic ecosystems may modify their functioning via impacts on the functional role of a freshwater shrimp (*Gammarus roeseli*).

2.2 Possible impacts on invertebrates including estuarine/marine invertebrates

Shannon K. (2013) noted that estuarine and marine sediments are a probable end point for many engineered nanoparticles due to enhanced aggregation and sedimentation in marine waters, as well as uptake and deposition by suspension-feeding organisms on the seafloor. They tested whether three heavily used metal oxide engineered nanoparticles, zinc oxide (ZnO), copper oxide (CuO), and nickel oxide (NiO) were toxic to an estuarine amphipod, *Leptocheirus plumulosus* and found that the accumulation of metals in amphipod tissues increased with exposure concentrations for all three NPS, suggesting possible exposure pathways to higher taxa.

Baun et al (2008) noted a lack of data in the field and noted that the limited number of studies has indicated acute toxicity in the low mgl^{-1} range and higher of engineered nanoparticles to aquatic invertebrates, although some indications of chronic toxicity and behavioural changes have also been described at concentrations in the high μgl^{-1} range.

Gagne et al (2008) looked at toxic effects of cadnium-telleuride (CdTe) quantum dots on freshwater mussels at various concentrations greater than 1mg/l. Some physiological impacts were recorded at these high concentration levels. Peyrot et al. (2009) reported similar effects. Conway et al. (2014) looked at the implications of trophic transfer and accumulation of cerium oxide CeO_2 nanoparticles in a marine mussel (*Mytilus galloprovincialis*) through two exposure methods namely direct and through sorbtion to phytoplankton. Approximately 99% of CeO_2 was captured and excreted in pseudofeces and average pseudofeces mass doubled in response to CeO_2 exposure. Clearance rates increased with CeO_2 concentration but decreased over time in groups exposed to CeO_2 directly, indicating stress.

Mouneyrac et al (2014) found that metal-based NPs in general were highly agglomerated/aggregated in seawater. Both metal forms (nanoparticulate, soluble) were generally bioaccumulated in two marine invertebrates, the bivalve mollusc *Scrobicularia plana* and the annelid polychaete *Hediste diversicolor.* Cozzaria et al, (2015) found that when the marine annelid polychate *N. diversicolor* is exposed to dissolved, nano and bulk silver (Ag) via spiked sediments, it showed an oxidative stress response.

Canesi et al, (2012) concluded that bivalves represent a particularly suitable model for investigating the effects and mechanisms of action underlying the potential toxicity of NPs in marine invertebrates. As suspension-feeders, they have highly developed processes for cellular internalization of nanoparticles integral to key physiological functions such as intra-cellular digestion and cellular immunity.

Baker et al, (2013) notes that benthic, sediment-dwelling and filter feeding organisms are most at risk. In marine systems, metal oxide (MeO) NPs can absorb to micro-organisms with potential for trophic transfer following consumption. The author also notes that environmentally-realistic metal oxide NPs concentrations are unlikely to cause significant adverse acute health problems, however sub-lethal effects e.g. oxidative stresses have been noted in many organisms, often deriving from dissolution of Ag, Cu or Zn ions, and this could result in chronic health impacts on such organisms.

2.3 Potential impacts on fish

Ostaszewska et al, (2016) looked at effects of silver (AgNPs) and copper (CuNPs) nanoparticles on larval Siberian sturgeon (*Acipenser baerii*) after 21 days of exposure. Toxicity tests were done in triplicates for each concentration of AgNPs 0.1, 0.5, 1.5 mg L^{-1} and CuNPs 0.01, 0.05, 0.15 mg L^{-1}. The results indicate that AgNPs and CuNPs exposure at these high levels negatively influenced survival; body length and mass; and morphology and physiology of the epidermis, gills, and liver of Siberian sturgeon larvae.

Handy et al (2011) notes that exposure to nanoparticles in the water column can cause respiratory toxicity involving altered ventilation, mucus secretion and gill pathology. Sub lethal concentration of various nanoparticles for fish ranged from 100 μg L^{-1} to 1 mg L^{-1}, while the lethal concentration of nanoparticles reach the milligrams per liter range.

Mehmet (2013) looked at sub-lethal effects of exposure of low and high concentrations of titanium dioxide nanoparticles (TiO2 NPs) on goldfish (*Carassius auratus*) and no significant accumulation in the muscle and brain of the fish was detected. However, titanium oxide (TiO2) NPs exposure inhibited growth of the goldfish. Scwon et al, (2010) showed that exposure of silver NPs to rainbow trout, at concentrations close to current estimations of environmental levels, can result in accumulation of silver in the gills and liver of fish and can affect likely oxidative metabolism in the gills.

2.4 Potential impacts on birds and mammals

Information looking at the potential impacts of nano-particles on wild mammal and bird populations, either through direct toxicity or bioaccumulation, is very limited. A review of published studies by Shah (2010) found that no studies were published on the toxicity of nanoparticles to birds. Some information on domestic birds is available. Sawosz et al. (2009) found that nanoparticles of silver do not affect growth, development and DNA oxidative damage in chicken embryos when hydrocolloids (0.3 ml), containing 50 ppm of nanoparticles, were injected in ovo prior to incubation of eggs. However, most such studies focus on the potential beneficial use of nanoparticles as food supplements for commercial poultry.

2.5 Limitations of available data

As an emerging field, a number of researchers have pointed out that data is lacking. A review of published studies by Shah (2010) found that that 42% of the studies involved measuring the toxicity of nanoparticles against pure microbial cultures, 18% of the ecotoxicity studies used fish or fish cells, 20% used daphnids and shrimp, 8% used plants, and fewer than 5% used worms. Although the pool of literature may seem quite large, glaring absences are apparent including birds and honey bees.

Matrangaa (2012) points out that whilst there is not much data available for gauging the effects of engineered nanoparticles on marine wildlife, the ultimate ecotoxicological impacts of chronic exposure to ENPs should be investigated further using laboratory tests and field studies. Mehmet (2013) notes that although aquatic species are at risk of exposure to the NPs, there is currently little known about their uptake, potential toxic effects, and behaviour in aquatic systems.

Handy et al, (2012) notes that rapid and reliable measurement methods for engineered nanoparticles in the tissues of organisms are needed to understand uptake and bioavailability, but also to ensure correct interpretation of ecotoxicity test results for risk assessments. Research with ecologically relevant test species and in real environmental scenarios is needed.

2.6 Conclusions

In general the literature review on the potential for biological and ecological impacts from engineered nanoparticles indicates that NPs in general can be aggregated in seawater and marine/estuarine bottom sediments. Lethal effects have been reported at high concentrations (generally in the mg/l range) in laboratory studies. Sub-lethal impacts such as oxidative stress have been reported and could potentially occur at environmentally realistic levels with respect to fish and invertebrates. Macro-invertebrate suspension feeders such as mussels may be at greater risk although work to quantify such effects via field studies is generally lacking. Some workers have reported impacts on fish but there is a paucity of information in relation to birds and mammals such as otter.

Although there are theoretical pathways by which impacts could occur at higher trophic levels, researchers have noted the paucity of information relating to ecosystem impacts or impacts on vertebrates such as birds. At the present time there is no clear scientific evidence which indicates that the levels of nanoparticles likely to realistically occur in the environment represent a significant risk to birds feeding on macro-invertebrates in estuarine sediments or to piscivorous birds listed as features of interest for the Cork Harbour SPA.

3. Conclusions on Nanoparticle air Emissions From Waste-To-Energy Facilities

Research has been conducted over the last fifteen years on emissions from incinerators in terms of nanoparticle size and numbers[1]. Nanoparticles (also referred to as ultra-fine particles (UFPs)) range in size from 1 - 100 nm. Nanoparticles in the environment may be either engineered nanoparticles or nanoparticles from a range of natural or combustion sources. As a worst-case, it has been assumed that the levels of nanoparticles reported in the literature studies below are 100% engineered nanoparticles.

A paper undertaken in 2001 (Zurcher et al, 2001) studied the emission of nanoparticles from modern municipal waste incinerators including a detailed investigation of particle numbers and particle size distribution. The study concluded that:

"The removal efficiency for PM_{10} of the flue gas treatment systems in all plants is very good. The number concentration of most plants is in the same order of magnitude as ambient air. According to our measurements we can state that waste incineration plants with up-to-date flue gas cleaning systems are not a relevant source for the emission of ultrafine particles into the environment. Particles above 1 micron are almost completely eliminated".

[1] Refer also to the evidence provided by Dr Edward Porter in which this research is considered

More recent research has been undertaken by an Italian research team (Buonanno et al, 2011a, Buonanno et al, 2011b, Buonanno et al, 2010) which focussed on a series of modern waste-to-energy facilities in Italy.

One of these papers (Buonanno et al, 2011b) reviewed emissions from five facilities in Italy with a range of furnaces and flue-gas cleaning technology. The facilities included moving grate, roller-type grate and fluidized bed reactors. In terms of abatement, the technology included wet, semi-dry and dry processes, spray absorber systems and fabric filters. Four of the five incinerators installed fabric filters, the exception being a facility which processed biomass which had a wet scrubber as the preferred abatement technology.

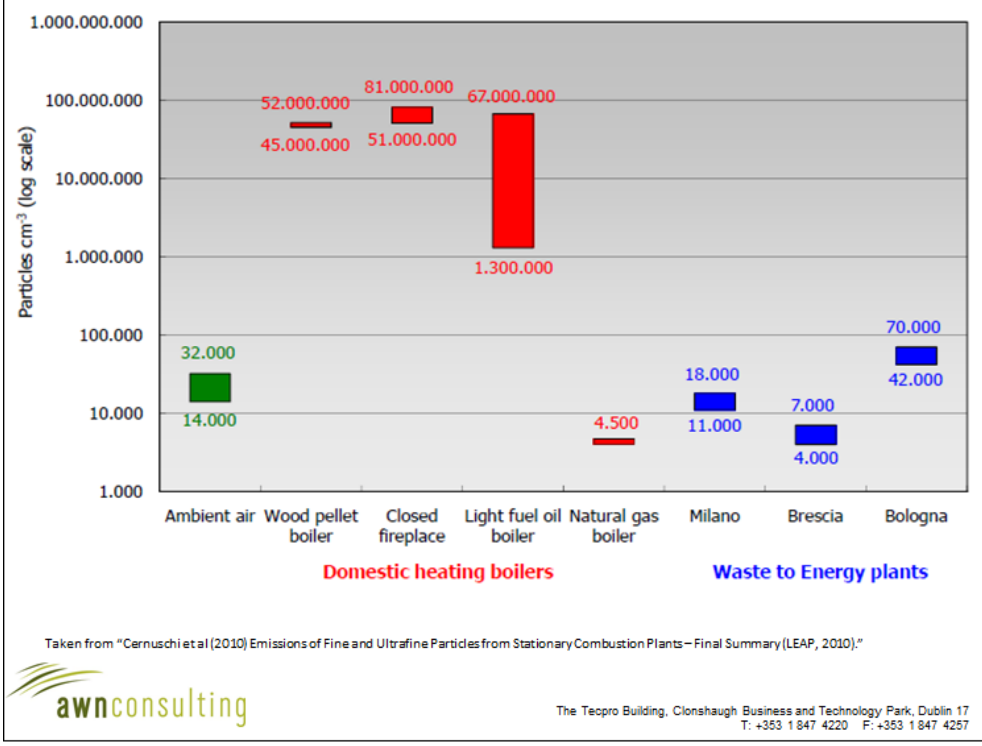
At two of the incinerators, measurements of nanoparticles were taken both prior to and after the fabric filter in order to determine the abatement efficiency of the fabric filter in the nanoparticle range. The results from the efficiency test were that fabric filters could achieve an efficiency of 99.99% over the entire measurement range (from 6 nm – 1000 nm) in terms of particle numbers.

In terms of the overall results from the four MSW incinerators, the average concentration ranged from 0.4 – 6.0 x 10^3 particles cm^{-3}. The study concludes by stating:

*"**Implications**: The main implication of the study is that the use of a fabric filter in the flue gas treatment section of incinerators is able to guarantee very low concentrations in the stack in terms of UFPs. As regards the incineration plants, a further implication of the proposed study is that an a priori negative social response seems to be unjustified when referred to the ultrafine particle emissions."*

Buonanno et al, (2010) undertook a review of nanoparticles in ambient air downwind of a waste-to-energy facility in 2010. The facility was a modern moving grate facility with a semi-dry abatement system (SNCR, spray absorber system and a fabric filter). The average total number concentration was lower than 1.0 x 10^4 particles cm^{-3}. The study concluded that the results were typical of a rural site and that most of the elements could be attributed to long-range transport from other natural and/or anthropogenic sources.

Another study, by Cernuschi et al (2010), found that emissions of nanoparticles (in terms of particle numbers) from WTE facilities with fabric filters were typically similar to or lower than ambient air as shown in Figure 1. The results were compared to other combustions sources, such as wood pellet boilers, closed fireplaces and light fuel oil boilers, which were typically orders of magnitude higher.



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Reference
16/8939AT01

Figure 1
UFP Particle Number (particles cm^{-3}) – Three Modern Incinerators In Italy Compared To Ambient Air & Other Combustion Sources

Buonanno et al (2009) also assessed the emissions of nanoparticles from incinerators and compared them to emissions from other sources:

> *"In terms of total particles emitted, 20 vehicles (with a percentage of HGVs between 6% and 8%) moving along a 3 km highway length in typical traffic conditions, are equivalent to one hour emission of the waste-to-energy plant."*

A recent review undertaken by a team lead by Roy Harrison in the UK (Kumar et al, 2013) stated the following in terms of nanoparticles from incinerators:

> *"However, the work of Buonanno et al. (2008, 2009a, 2011) and Angelucci et al. (2010) indicates that the flue gas treatment used on current technology incinerators is highly efficient, reducing nanoparticle concentrations in stack gases to levels comparable with ambient air. Consequently, the UFPs associated with MSW incineration are likely to be considerably smaller in quantity compared with a major source such as road traffic emissions."*

4. Potential impacts from engineered particles in Boiler Ash and Flue Gas Cleaning Residues - NIS conclusions

Circa 2,000 tonnes per annum of boiler ash and circa 9,104 tonnes per annum of flue gas cleaning residues will be produced in the waste-to-energy facility at Ringaskiddy. The flue gas cleaning residues will be in the form of fine particles which will include engineered nanoparticles. As noted in sections 4.5.8 and 4.5.9 of the NIS, these residues will be disposed of to a landfill for hazardous waste after treatment if necessary or recovered to a salt mine, either in Ireland, if one is available, or abroad. Potential impacts on Natura 2000 sites were screened out due to the following:

- The shipping containers used for transport are designed and operated in line with international standards. The regulation of the transport of the boiler ash and flue gas residues would be subject to Trans Frontier Shipment (TFS) licence which is a licence which must be approved by the origin/destination/transit authorities consenting to the movement/transit and acceptance of wastes between EU member states.
- The residues will be collected on the site in sealed silos. The silos are emptied into a tanker via a sealed connection. This will ensure that there are no fugitive releases on the site.
- It is noted that the accident risk during shipping of the boiler ash and flue gas residues is low. Van Den Bosch are the preferred international logistic services provider which transports such residues for Indaver. They note that in the 51 years of their history no container has ever fallen overboard and no ship has sunk with their containers on board.
- The addition of water leads to the residues solidifying. Thus in event of a shipping accident and if the transport container were to lose integrity, the residues would solidify on contact with water and solidified residues will be salvaged from the sea bed.

Section 4.5.8 of the NIS (DixonBrosnan, 2015) concluded that *"Given the extremely low risk of an accident, the low risk of leakage from the transport containers, the fact that the residues will solidify on contact with water, no appreciable impacts on Natura 2000 sites along the shipping route from the disposal of this material will occur."*

5. Conclusions

The Natura Impact Statement appraised the potential for significant impacts arising from the proposed development on Natura 2000 sites within a 20km radius. Following screening the only Natura 2000 site for which potential impacts had been identified was the Cork Harbour SPA which is located approximately 0.5km from the proposed development site at its closest point.

Theoretically impacts on the SPA could arise if high levels of NPs were to reach the aquatic environment, via emissions or accidental spillage of flue gas residues.

A literature review (Section 2) indicates that engineered nanoparticles could theoretically impact on marine macro-invertebrates and fish, including species which may form part of the diet of birds listed as features of interest for the Cork Harbour SPA. At the present time however, there is no clear scientific evidence which indicates that the levels of nanoparticles likely to realistically occur in the existing environment represent a significant risk to birds feeding on macro-invertebrates in estuarine sediments or to piscivorous birds listed as features of interest for the Cork Harbour SPA.

A literature review (Section 3) on nanoparticle emissions from Waste-To-Energy facilities concluded that the use of a fabric filter in the flue gas treatment systems leads to very low levels of engineered nanoparticles in air emissions. The air emissions from the facility are not predicted to be a significant source of engineered nanoparticles and it is further noted that the Cork Harbour SPA is located 0.5km from the proposed facility at its closest point.

Nanoparticles will be present in flue gas residues. It was concluded by the NIS (Section 5 above) that the risk of accidental release of flue gas residues during transport is not considered significant and this potential impact was screened out in the NIS.

There will be no process aqueous discharges from the facility. The only aqueous discharges to the marine environment during construction or operation will be surface water and there will be no pathway for engineered nanoparticles to enter the surface water. There is no direct pathway to water, it is indirect and the particle concentrations in air associated with the waste to energy plant are effectively insignificant when compared with background. Particles in air may over time deposit on water but in this case the water body is Cork Harbour with a daily tidal flux of some 57 million m3/day, providing many orders of magnitude dilution of any particles depositing on water.

For the receptor to be impacted there needs to be a significant concentration of particles in the water. From literature it is indicated that significant effects are most likely to occur at the mg/l level, whereas with the available dilution and the insignificantly small emission, it is not possible that the mg/l levels could ever be reached. Therefore, the potential for significant impacts on prey items for birds within the Cork Harbour SPA from engineered nanoparticles is considered extremely remote for the foreseeable future.

Following on from this comprehensive assessment of the potential impacts on the qualifying interests and conservation objectives for Natura 2000 sites, it has been concluded that the proposed development will not have an adverse effect on the integrity of any Natura 2000 sites including the Cork Harbour SPA.

6. References

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An Roinn
Ealaíon, Oidhreachta agus Gaeltachta
Department of
Arts, Heritage and the Gaeltacht

Oral Hearing Submission (Strategic Infrastructure Application)

To:	An Bord Pleanála.
Re:	Ringaskiddy Energy Recovery Facility.
Your ref.:	PA0045
Our ref.:	SID-2016-C0-03
Date:	22 April 2016

Question from Cllr Marcia D'Alton

Effect of nanoparticles: Aquatic Toxicology paper

The paper referred to in the above oral question to Department of Arts, Heritage and the Gaeltacht (National Parks and Wildlife Service) is:

Gagne, F., Auclair, J., Turcotte, P., Fournier, M., Gagnon, C., Sauvé, S. and Blaise, C. (2008) Ecotoxicity of CdTe quantum dots to freshwater mussels: Impacts on immune system, oxidative stress and genotoxicity. *Aquatic Toxicology* **86**: 333-340.

The abstract of the paper is given in Appendix 1. The paper reports on effects of cadmium telluride dots (which are small nanoparticles used in optoelectronic devices such as solar cells and biosensors[1]) in concentrations of greater than 1 mg/litre on freshwater mussels (*Elliption complanata*). This paper, and a subsequent 2009 paper from the same research group[2], reported physiological effects of cadmium on mussels. However, it may be feasible to recycle cadmium telluride photovoltaic systems in the future to avoid their incineration[3].

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A similar study[4] examined the marine Mediterranean mussel in a laboratory experiment, and found oxidative stress in the digestive gland from copper oxide nanoparticles at concentrations of 10 µg Cu. Such effects, of nanoparticles on mussels were recently reviewed by Canesi *et al.* in 2012[5] (and also included marine mussels *Mytilus*, which are present in Cork Harbour and form part of the diet of oystercatchers, and are therefore relevant to the Special Protection Area). It is worthwhile citing from this review:

"Due to the continuous development and production of manufactured nanomaterials or nanoparticles (NPs), their uptake and effects in the aquatic biota represent a major concern. Estuarine and coastal environments are expected to represent the ultimate sink for NPs, where their chemical behavior (aggregation/agglomeration) and consequent fate may be critical in determining the biological impact. ... *in vivo* exposure to NPs indicates that, due to the physiological mechanisms involved in the feeding process, NP agglomerates/aggregates taken up by the gills are directed to the digestive gland, where intra-cellular uptake of nanosized materials induces lysosomal perturbations and oxidative stress. Overall, bivalves represent a particularly suitable model for investigating the effects and mechanisms of action underlying the potential toxicity of NPs in marine invertebrates."

The overall impression from this review is that there is potential for sub-lethal effects but that little scientific data on the risk of effects in the wild is available because of the recency of this technology to the environment. In a recent article on the impacts of metal and metal oxide nanoparticles on marine life, Baker *et al.* (2014)[6] concluded as follows:

"Increasing use of metal and metal oxide nanoparticles [Me(O)NPs] in products means many will inevitably find their way into marine systems. Their likely fate here is sedimentation following hetero-aggregation with natural organic matter and/or free anions, putting benthic, sediment-dwelling and filter feeding organisms most at risk. In marine systems, Me(O)NPs can absorb to micro-organisms with potential for trophic transfer following consumption. Filter feeders, especially bivalves, accumulate Me(O)NPs through trapping them in mucus prior to ingestion. Benthic in-fauna may directly ingest sedimented Me(O)NPs. In fish, uptake is principally via the gut following drinking, whilst Me(O)NPs caught in gill mucus may affect respiratory processes and ion transport. Currently, environmentally-realistic Me(O)NP concentrations are unlikely to cause significant adverse acute health problems, however sub-lethal effects e.g. oxidative stresses have been noted in many organisms, often deriving from dissolution of Ag, Cu or Zn ions, and this could result in chronic health impacts."

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[4] Gomes, T., Pereira, C.G., Cardoso, C., Pinheiro, J.P., Cancio, I., Bebianno, M.J. (2012) Accumulation and toxicity of copper oxide nanoparticles in the digestive gland of *Mytilus galloprovincialis*. *Aquatic Toxicology* **118**: 72-79.

[5] Canesi, L., Ciacci, C., Fabbri, R., Marcomini, A., Pojana, G. and Gallo, G. (2012). Bivalve molluscs as a unique target group for nanoparticle toxicity. *Marine Environmental Research* **76**: 16-21.

[6] Baker, T.J., Tyler, C.R. and Galloway, T.S. (2014) Impacts of metals and metal oxide nanoparticles on marine organisms. *Environmental Pollution* **186**: 257-271.

Waiser *et al.* (2012)[7] assessed nanoparticles in a municipal solid waste incinerator:
"Here, we show that cerium oxide nanoparticles introduced into a full-scale waste incineration plant bind loosely to solid residues from the combustion process and can be efficiently removed from flue gas using current filter technology. The nanoparticles were introduced either directly onto the waste before incineration or into the gas stream exiting the furnace of an incinerator that processes 200,000 tonnes of waste per year. Nanoparticles that attached to the surface of the solid residues did not become a fixed part of the residues and did not demonstrate any physical or chemical changes. Our observations show that although it is possible to incinerate waste without releasing nanoparticles into the atmosphere, the residues to which they bind eventually end up in landfills or recovered raw materials, confirming that there is a clear environmental need to develop degradable nanoparticles."

The above is only a sample of the scientific literature on this subject. Nevertheless, it can be concluded that, although the supposition that engineered nanoparticles have adverse effects in marine ecosystems such as Cork Harbour is not scientifically verified from the above sample of scientific literature, nevertheless such nanoparticles have known physiological effects and therefore should be fully assessed in the Natura Impact Statement (NIS). It is recommended, therefore, that a review of the scientific literature on effects of engineered nanoparticles likely to originate from the proposed incinerator is undertaken, and an assessment of their potential effects on Cork Harbour SPA is included, as a supplement to the NIS.

Amended recommended condition

The following is the amended wording of the recommended monitoring condition referred to in evidence by the Department to the Oral Hearing on 21 April 2016 (amendment in italics):

Monitoring of PCDDs and PCDFs will be carried out in livers of fish which form part of the diet of piscivorous birds in Cork Harbour Special Protection Area. Fish samples will be collected in shallow waters (<5m depth) from Whitegate Bay and *from Monkstown Creek* (avoiding wastewater discharge areas) by competent aquatic ecologists and samples will be analysed in an accredited laboratory. Monitoring will be carried out every 5 years after commencement of operation, and a baseline data-set will be established prior to the commencement of the operation of the incinerator. Reports of the baseline and monitoring will be forwarded to the planning authority and the National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht.

Reason: To ensure that the predictions of no adverse effects on Cork Harbour Special Protection Area are met.

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[7] Waiser, T. *et al.* (2012) Persistence of engineered nanoparticles in a municipal solid-waste incineration plant. *Nature Nanotechnology* **7**: 520-524.

Appendix 1.

Abstract of Gagne *et al.* (2008):

"The purpose of this study was to examine the toxic effects of cadmium–telluride (CdTe) quantum dots on freshwater mussels. *Elliption complanata* mussels were exposed to increasing concentrations of CdTe (0, 1.6, 4 and 8 mg/L) and cadmium sulfate ($CdSO_4$, 0.5 mg/L) for 24 h at 15 °C. After the exposure period, they were removed for assessments of immunocompetence, oxidative stress (lipid peroxidation) and genotoxicity (DNA strand breaks). Preliminary experiments revealed that CdTe dissolved in aquarium water tended to aggregate in the particulate phase (85%) while 15% of CdTe was found in the dissolved phase. Immunotoxicity was characterized by a significant decrease in the number of hemocytes capable of ingesting fluorescent beads, and hemocyte viability. The cytotoxic capacity of hemocytes to lyse mammalian K-562 cells was significantly increased, but the number of circulating hemocytes remained unchanged. Lipid peroxidation was significantly increased at a threshold concentration of 5.6 mg/L in gills and significantly reduced in digestive glands at a threshold concentration <1.6 mg/L CdTe. The levels of DNA strand breaks were significantly reduced in gills at <1.6 mg/L CdTe. In digestive glands, a transient but marginal increase in DNA strand breaks occurred at the lowest concentration and dropped significantly at the higher concentrations. A multivariate analysis revealed that the various response patterns differed based on the concentration of CdTe, thus permitting the identification of biomarkers associated with the form (colloidal vs. molecular) of cadmium."