Appendix R – Human Health Risk Evaluation

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Dubai Waste Management Center

Human Health Risk Assessment

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1. Introduction

Hitachi Zosen Inova Ltd – AG Abu Dhabi (Hitachi, HZI), Besix S.A. Sharjah Branch (Besix) and Itochu Corporation (Itochu) are engaged by the Dubai Municipality for the proposed Waste Management Center (WMC) to be constructed in the Emirate of Dubai of the United Arab Emirates (UAE). The proposed WMC (the Project) will utilise municipal solid waste (MSW) from the Emirate of Dubai, processing 5,664 tonnes of waste per day at 9.5 MJ/kg net calorific value (NCV) nominal design capacity. The WMC will be the largest of its kind to be developed in the world.

The Project site is located approximately 17 km east of Bur Dubai and 10 km south-east of the Dubai International Airport. It is estimated that the facility will cover an area of approximately 506,096.14 m^2. Figure 1 shows the location of the WMC in the Emirate of Dubai within the UAE.

Figure 1 Project location

1.1 Project description

The WMC will recover energy through the production of electricity from what would have been waste material sent to landfill, and will produce incinerated bottom ash (IBA) which can be recycled as an aggregate. The electricity generated will be exported to the electrical grid of DEWA. The design of the WMC consists of five lines, each with an operating capacity of 47.2 tonnes per hour (amounting to 5,664 tonnes per day (tpd) for the facility). Once in operation, the plant will reduce the waste volume to a small percentage and therefore transfer of waste to landfill and ultimately traffic/traffic emissions will be reduced.

1.2 Purpose

This report serves as the Human Health Risk Assessment (HHRA) for the Project. The purpose of this HHRA appendix is to evaluate human health concerns through direct and indirect (i.e., ingestion and dermal contact) exposures to potential air emissions from the proposed WMC under the operating case in which a thermal load of 100% is assumed. The evaluation focuses on the potential impacts associated with emissions from the facility and is based upon information provided in the air quality assessment report (GHD, 2019). Occupational exposure inside the WMC has not been evaluated in this report.

1.3 Report Organization

Existing environmental conditions within the Local Risk Assessment Study Area are described in this HHRA Report, followed by an analysis of the potential adverse effects of the Project on the health of the population of human receptors when the thermal load of the future emissions is 100%. The key components of this HHRA Report are as follows:

- Section1.0: A general introduction and background information about the Project and the HHRA
- Section 2.0: The assessment areas and operational scenarios are described
- Section 3.0: The contaminants of concern (COCs) are presented
- Section 4.0: The baseline air conditions at the assessment area are described
- Section 5.0: The hazards of the HHRA are presented
- Section 6.0: The exposure routes the HHRA are presented
- Section 7.0: The exposure response to emissions are presented
- Section 8.0: A summary of conclusions based on the HHRA
- Section 9.0: The references cited in the HHRA Report are documented

2. Assessment Area and Scenarios

2.1 Assessment Area and Sensitive Receptors

The Assessment Area of the HHRA was considered to evaluate changes in air quality as a result of future air emissions originating from the five point sources (i.e., tall stacks), which are associated with fuel combustion sources (boilers). It is estimated that the facility will cover an area of approximately 506,096.14 m^2. Figure 2 shows the proposed location of the five stacks.

The Project will be located near an existing waste landfill site in Warsan, Dubai, specifically Warsan 2 and the facility will be situated east of the Al Aweer Sewage Treatment Plant (STP). The areas immediately surrounding the Project site generally consist of industrial facilities including the Dubai Electrical and Water Authority (DEWA) and the Dubai Police Transport Impounding Area. The atmospheric dispersion and deposition of emissions generated from the Project were evaluated to determine if ambient air within the residential and industrial areas surrounding the Project would be impacted adversely by the project. As such, the Assessment Area evaluated in the HHRA consists of all lands within a 5-kilometre (km) radius of the Project.

Sensitive receptors are classified as places where people are likely to work or reside. This may include dwellings, schools, hospitals, offices or public recreational areas (NSW DEC 2005). 14 sensitive receptors have been identified within 5 km from the Project and are detailed in Table 1. Sensitive receptor locations are shown on Figure 2 along with the location of the five stacks.

Table 1 Sensitive receptors

ID	Description	Location (m UTM)	Distance from site (km)	Elevation (m ASL)
RES1	Dubai International City- EMR 14, Emirates Cluster	341174 E 2783650 N	1.4	29
RES2	International City Phase II (under construction)	340779 E 2782024 N	1.3	30
RES3	Residential Vilas (Desert Palm)	342995 E 2784091 N	0.3	43
RES4	AL Warqa 4 (north of Al Awir Road)	342720 E 2784920 N	1.1	28
REL5	Dragon Mart Mosque	341316 E 2784651 N	1.6	24
COM6	Dragon Mart Commercial Centre	341417 E 2784708 N	1.6	21
COM7	Dubai Textile City	341250 E 2784434 N	1.6	22
COM8	Desert Palm Resort and Hotel	343498 E 2784272 N	0.6	47
COM9	Dubai Plant Nursery	344076 E 2783294 N	0.6	47
RA10	Dubai Safari Park (north of Al Awir Road)	343361 E 2784988 N	1.3	26

ID	Description	Location (m UTM)	Distance from site (km)	Elevation (m ASL)
RA11	Pivot Fields	342675 E 2783943 N	0.15	42
RA12	Desert Palm Polo Club	343130 E 2784366 N	0.6	43
RA13	Desert Palm Riding Schools	343433 E 2783988 N	0.3	40
RA14	Warsan Lake	340905 E 2783266 N	1.4	30

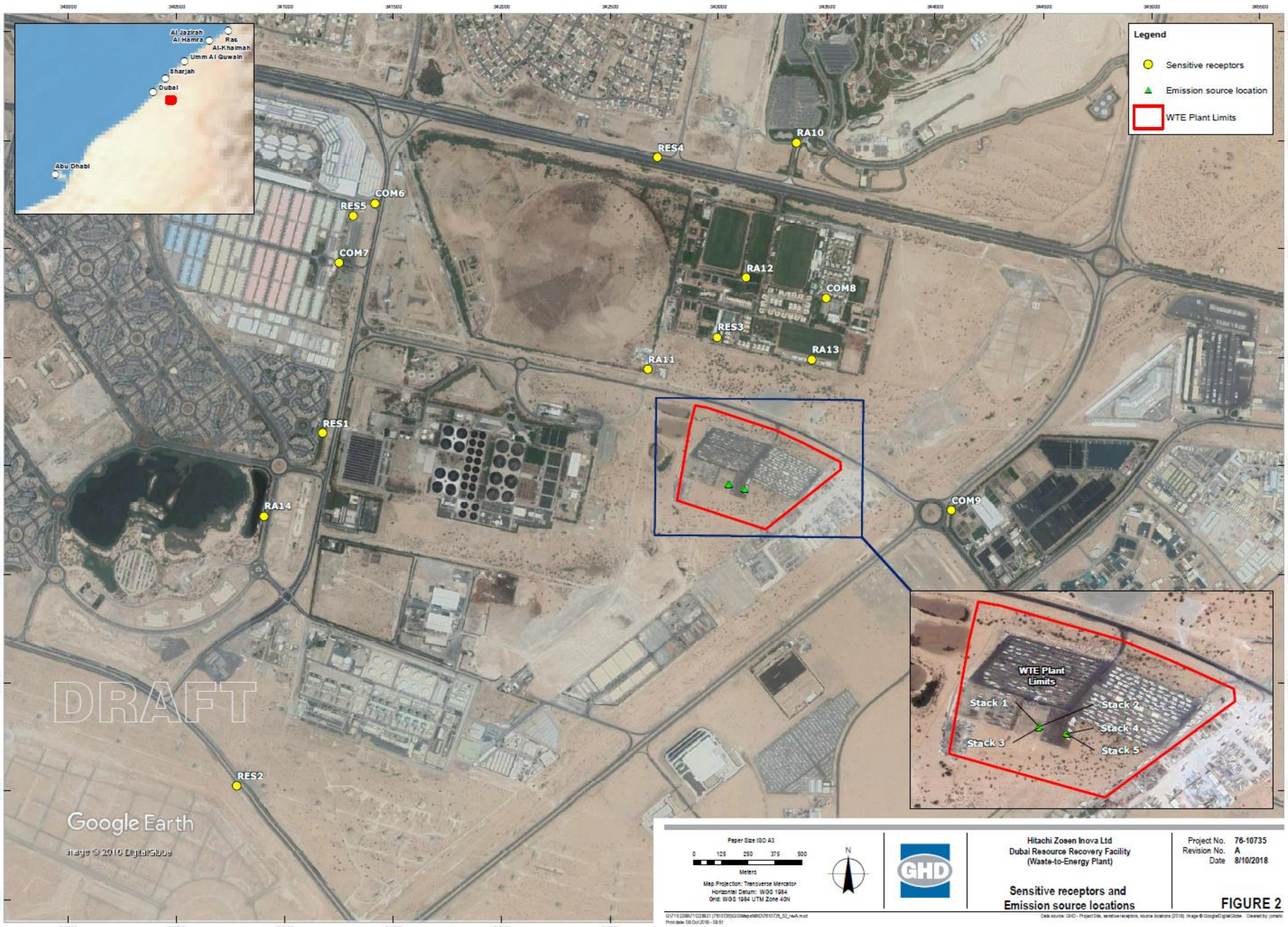

Figure 2 Sensitive receptors and emission source locations

3. Identification of Contaminants of Concern (COCs)

The exact composition of emissions depends somewhat upon the characteristics of the solid waste being incinerated. However, pollutants emitted by waste incinerators generally fall into six categories (Vinceti *et al*., 2005):

- Particulate matter
- Acid gas emission
- Heavy metals
- Organic emission (dioxin and furans)
- Volatile organic compounds
- Polycyclic aromatic hydrocarbons

These pollutants can impact human health through inhalation, incidental ingestion, and dermal contact. Deposition of toxic materials can lead to any of the indicated exposure routes.

Baseline air concentrations were established for some of the COCs and these concentrations are discussed in Section 4.1. The baseline, or background, air concentrations were used to evaluate the existing health risk associated with the existing and modelled air quality at the sensitive receptor locations.

The potential changes in the air quality for each COCs listed above were assessed using the emission data and air dispersion modelling. The dispersion modelling was performed using the United States Environmental Protection Agency (USEPA) AERMOD air dispersion model. A description of the model selection, methodology, and validation is provided in the Air Quality Assessment Report (GHD, 2019).

4. Description of Baseline Conditions

Background air pollutant concentrations have been considered, in addition to the proposed generated emissions from the WMC, to assess how the cumulative levels compare to the ambient air quality assessment criteria. Air quality in the Emirate of Dubai will vary depending on weather conditions and the nature of the location of the area (e.g., urban, industrial, agricultural, etc.). Air quality monitoring stations (AQMS) measure air pollutants in the UAE as required in Cabinet Decree 12 of 2006.

A description of existing ambient air quality near the Project site is presented in this section using information from the AQMS to provide context for the modelling results. Relevant background concentrations are adopted for cumulative assessment of modelling results against the assessment criteria.

4.1 Annual average ambient air quality

AQMS' situated in residential areas (Deira and Mushrif Park) and industrial areas (Warsan and Dubai International Airport) of the Emirate of Dubai continuously monitor criteria pollutants such as PM_{10}, SO_2, NO_2 and CO. The locations of these AQMS are shown in Figure 3.

The results of air quality monitoring at the four stations (where available) in 2017 are provided in Section 4 (Table 4-1) of the Air Quality Assessment Report (Appendix N of the EIA). Annual average PM_{10} exceeds the WHO limit, as shown in red text, at both available stations. Annual SO_2 measurements comply with the UAE Federal standard for all stations. The WHO annual NO_2 standard is exceeded at three out of the four stations. There are no annual standards for CO, although concentrations measured at all four stations are considered relatively low.

Figure 3 AAQMS locations

4.1.1 Adopted annual average background concentrations

For a cumulative assessment of annual average concentrations, data presented in Section 4 (Table 4-1) of the Air Quality Assessment Report (Appendix N of the EIA) was adopted as background concentrations. As the sensitive receptors in this assessment are located in residential areas, data from the closest residential AQMS was used, this being Mushrif Park.

4.2 1-hour average ambient air quality

Dubai Municipality provides the highest recordings at several monitoring sites in the Emirate of Dubai as Air Pollution Indicators. Data from 11 AQMS provided in Section 4 (Table 4-2) of the Air Quality Assessment Report (Appendix N of the EIA) showing the highest recorded 1-hour concentrations for industrial and residential areas. The highest recordings for NO_2 exceed the WHO standards of 200 µg/m^3 for at least one of the three years presented at all AQMS except for Emirates Hill. It is noteworthy that none of the concentrations exceed the less stringent UAE standard of 400 µg/m^3. All measurements of CO and SO_2 at the available AQMS are below the respective standards of 30,000 µg/m^3 and 250 µg/m^3.

4.2.1 Adopted 1-hour background concentrations

For a cumulative assessment of 1-hour average concentrations, these Air Pollution Indicators (where available) have been adopted as the background concentrations and are considered a conservative estimate. As the sensitive receptors in this assessment are located in residential areas, data from the closest residential AQMS was used, this being Mushrif Park. Data from the most recent monitoring period (2017) was used, highlighted in Section 4 (Table 4-2) of the Air Quality Assessment Report (Appendix N of the EIA) in bold.

5. Hazards

Many studies have been performed at incinerators around the world to characterize the health impacts associated with energy from waste (EfW) or waste to energy (WTE) plants. Emissions from the waste combustion process generally present the greatest potential risk for health impact. Incinerated bottom ash and flue gas treatment residues present potential risks from leachate at the disposal location and air dispersion of the residues if it is not properly covered or controlled.

5.1 Emissions

Contaminants evaluated in the dispersion model were: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), total suspended particles (TSP), acid gasses (HCl, HF, and NH3), dioxins (2,3,7,8 TCDD), mercury (Hg), and cadmium (Cd). Particulate matter (PM) with a diameter equal to or less than 10 microns (PM_{10}) and diameter equal to or less than 2.5 microns ($PM_{2.5}$) were conservatively estimated based on a ratio of 1:1 of TSP to PM_{10} and $PM_{2.5}$. The model predicted ground level concentrations (GLCs) for these parameters at each of sensitive receptor locations and the maximum domain concentration (referred to as the grid maximum). The model domain was set up using uniform Cartesian (gridded) receptors at a resolution of 50 m. 221 by 221 gridded receptors were set up to cover an area of by 11 km by 11 km covering the Project site.

The risk associated with incinerator emissions are discussed in more detail in the subsequent sections.

5.2 Ash

Short-term storage of bottom and flue gas treatment residues will be provided at the WMC. The incinerated bottom ash will be pretreated and managed by Dubai Municipality prior to use as aggregate on Dubai roadways. The flue gas treatment residues will also be managed by Dubai Municipality, however the final disposal option is currently not known but it is defined as a hazardous waste in most contexts.

Heavy metal concentrations in leachate from ash disposal present the greatest risk based on several studies (Alba *et al*., 1997) (Chichester and Landsberger, 1996) (Buchholz and Landsberger, 1995). Leachate could contaminate ground water which could subsequently lead to contamination of the marine environment or groundwater resources.

However, the pretreatment of the ash should stabilize it to control leachate thereby reducing the potential impacts to ground water. Furthermore, ground water was encountered between 7 to 15 metres below ground level. Consequently, adverse human health impacts from the leachate associated with ash re-use or disposal are not expected to be of consequence.

Airborne dust from the ash will be minimized through the use of covered vehicles and dust control measures at the facility. The potential risk to human health associated with airborne dust from the ash is similar to the potential risks associated with emissions from the incineration process and will be discussed generally as a component of emissions.

6. Exposure routes

Exposure to pollutants associated with MSW incineration could occur through inhalation, incidental ingestion, and dermal contact.

6.1 Inhalation

Pollutants of concern could be found in gas or particulate form emitted from the incinerator stack or residual ash. Inhalation of these gasses or particulates provides a pathway for pollutants to impact human health. Preliminary studies have been done to evaluate wind conditions and dispersion of emissions from the WTE plant as described in the Air Quality Assessment Report (GHD, 2019).

6.2 Ingestion

Incidental ingestion of particulate matter from incinerator emissions or airborne dust from bottom and fly ash is unlikely but could occur if these particulates were to settle on food or in water that is subsequently consumed by workers or the general public.

6.3 Dermal Contact

Dermal contact is possible for workers working with the incinerator ash. Deposition of particulates or airborne dust on non-workers under proper operation of the emission control systems is anticipated to be negligible. However, the management measures that will be in place should eliminated or minimize any potential exposure for the workers.

7. Exposure response

7.1 Inhalation

The air emissions dispersion modelling performed for this study estimated emissions of several contaminants of concern at key receptors within the 5 km of the proposed WMC. Contaminants evaluated in the dispersion model were: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), total suspended particles (TSP), acid gasses (HCl, HF, and NH3), dioxins/furans (2,3,7,8 TCDD), mercury (Hg), and cadmium (Cd).

The estimated emissions were compared against established emission criteria in the UAE and health-related exposure levels established by the World Health Organization (WHO), and the New South Wales, Australia Approved Methods for the Modelling and Assessment of Air Pollutants (AMMAAP). Tabulation of the comparisons can be found in Section 5 (Table 5-4 to Table 5-12) of the Air Quality Assessment Report (Appendix N of the EIA).

The potential health effects from short-term exposures were determined by using the predicted maximum 1-hour and 24-hour concentrations. The potential for acute health effects from exposure to a COC is evaluated by comparing either the 1-hour or 24-hour air concentration to an applicable criteria for a similar time period. A percentage of the criteria was also calculated and presented in the tables. If the percentage is less than 100 percent than the model air concentration should not result in an adverse effect to human health.

Of the parameters modelled, only (Cd) was close to guidance levels used for comparison. These will be discussed in the following sections.

7.1.1 Nitrogen Dioxide (NO_2)

As numerous epidemiological studies have used NO_2 as a marker for the mixture of combustion-related pollutants, in particular, those emitted by road traffic or indoor combustion sources, therefore, it has been difficult to provide a robust basis for the health effects associated with inhalation of NO_2 (WHO, 2005). However, epidemiological studies have shown that bronchitic symptoms of asthmatic children increase in association with annual NO_2 concentration, and that reduced lung function growth in children is linked to elevated NO_2 concentrations within communities already at current North American and European urban ambient air levels (WHO, 2005).

Section 5 (Table 5-4) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 1-hour, 24-hour and annual incremental GLCs for NO_2. Under the modelling assumption that 80% NOx is converted to NO_2 (for combustion sources), the highest predicted incremental concentrations fall below the assessment criteria.

The highest predicted 1-hour average concentration at a defined sensitive receptor was 66 $\mu g/m^3$ (Pivot Fields and Desert Palms Riding School). When added to the adopted 1-hour background concentration of 185 $\mu g/m^3$, the resulting concentration is 251 $\mu g/m^3$. This exceeds the WHO criteria of 200 $\mu g/m^3$, however remains comfortably below the UAE Federal criteria of 400 $\mu g/m^3$.

The highest predicted annual average concentration at a defined sensitive receptor was 3.0 $\mu g/m^3$ (Dubai Plant Nursery). When added to the adopted annual background concentration of 34 $\mu g/m^3$, the resulting concentration is 37 $\mu g/m^3$. This does not exceed the annual WHO criteria of 40 $\mu g/m^3$.

As the 1-hour average concentration plus the 1-hour background are above the WHO criteria, there may be times when 1-hour average of the NO_2 levels may result in decrease in pulmonary function for some individuals, particularly those with asthma.

7.1.2 Sulfur Dioxide (SO_2)

Inhalation exposure to SO_2 primarily impacts the respiratory system resulting in bronchoconstriction; asthmatics are particularly prone to adverse health impacts associated with exposure to SO_2 (ATSDS, 1998). Studies have been conducted in controlled chamber experiments for short-term exposure and observational studies in urban areas for 24-hour and long-term exposure (WHO, 2005).

The controlled chamber experiments indicate that "response to inhaled SO_2 is rapid, the maximum effect usually being reached within a few minutes" (WHO, 2005). However, lung function returns to normal after the exposure ceases.

Observation studies in urban areas provide estimates of the correlation between SO_2 concentrations in ambient air and mortality rate. Many of these studies indicate a correlation exists between a decrease in the ambient SO_2 concentrations and a decrease in mortality rates. However, "there is still considerable uncertainty as to whether SO_2 is the pollutant responsible for the observed adverse effects or, rather, a surrogate for ultrafine particles or some other correlated substance" (WHO, 2005). Using these studies, the WHO established 24-hour average target air quality guidelines for SO_2 concentrations. The WHO concluded that compliance with the 24-hours guideline would assure low levels for the annual average and, consequently, an annual average was not warranted.

The ATSDR within the US Department of Health and Human Services developed a toxicological profile for SO_2 as part of its evaluation of hazardous substances most commonly found at National Priority List sites identified under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). ATSDR evaluated clinical studies, occupational exposure incidents, and non-occupational exposure studies. Using these studies, the ATSDR established a minimal risk level (MLR) and lowest-observed-adverse-effect level (LOAEL). The MLR "is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure" (ATSDR, 1998). The acute ATSDR MRL for sulfur dioxide is 0.01 part per million (ppm) or 26.2 $\mu g/m^3$. Acute MRLs typically applied for 1 to 14 day exposures, therefore the acute ATSDR MRL is comparable to the more conservative WHO 24-hour average of 20 $\mu g/m^3$, therefore a direct comparison was not undertaken.

Section 5 (Table 5-5) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 1-hour, 24-hour and annual incremental GLCs for SO_2. The highest predicted incremental concentrations fall below the assessment criteria for all averaging periods.

The highest predicted 1-hour average concentration at a defined sensitive receptor was 21 $\mu g/m^3$ (Pivot Fields and Desert Palms Riding School). When added to the adopted 1-hour background concentration of 86 $\mu g/m^3$, the resulting concentration is 107 $\mu g/m^3$. This does not exceed the UAE Federal criteria of 350 $\mu g/m^3$.

The highest predicted annual average concentration at a defined sensitive receptor was 0.9 $\mu g/m^3$ (Dubai Plant Nursery). When added to the adopted annual background concentration of 6 $\mu g/m^3$, the resulting concentration is 6.9 $\mu g/m^3$. This does not exceed the annual UAE Federal criteria of 60 $\mu g/m^3$. Therefore, these modelled concentrations should not result in any adverse human health effects.

7.1.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is absorbed through the lungs and reacts in the blood stream with hemoglobin to form carboxyhemoglobin, which impairs the oxygen carrying capacity of the blood (HSDB, 2014). In addition to its reaction with hemoglobin, carbon monoxide combines with myoglobin, cytochromes, and metalloenzymes. Unchanged carbon monoxide is eliminated through the lungs when exhaled (HSDB, 2014). When carbon monoxide poisoning occurs, it has been reported to cause tissue damage, to include the heart, brain, liver, kidney, and muscles. The symptom and signs of carbon monoxide poisoning include neurological effects such as headaches, dizziness, weakness, nausea, confusion, disorientation, and visual disturbances, exertional dyspnea, and increase in pulse and respiratory rates (HSDB, 2014). Complications such as immediate death, myocardial impairment, hypotension, arrhythmias, and pulmonary edema occur frequently from carbon monoxide poisoning (HSDB, 2014).

Section 5 (Table 5-6) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 1-hour and 8-hour GLC for CO. The highest predicted incremental concentrations are below the assessment criteria.

The highest predicted 1-hour average concentration at a defined sensitive receptor was 108 $\mu g/m^3$ (Residential Villas). When added to the adopted 1-hour background concentration of 5477 $\mu g/m^3$, the resulting concentration is 5585 $\mu g/m^3$. This does not exceed the UAE Federal criteria of 10,000 $\mu g/m^3$. Therefore, these modelled concentrations should not result in any adverse human health effects.

7.1.4 Total suspended particles (TSP) and Particulate Matter (PM)

Total suspended particles (TSP) is a mass concentration of particulate matter (PM) in ambient air. Particulate matter (PM) refers to all airborne solid and liquid particles (except water) that are microscopic in size. Particle diameters may range from approximately 0.005 μm to 100 μm (CEPA, 1999). The most studied particles are the PM_{10} (particles that are 10 μm or less in diameter) and the $PM_{2.5}$ (particles that are 2.5 μm or less in diameter). PM_{10} is generally subdivided into a fine fraction (≤2.5 μm) ($PM_{2.5}$) and coarse fraction (>2.5 μm). Total suspended particulate (TSP) generally consists of particles less than 40 μm. Up to 80 % of PM_{10} and 60% of TSP are made up of $PM_{2.5}$ (CEPA, 1999). The major components of the fine fraction include sulphate, nitrate, ammonium, lead, elemental carbon, metals, and hundreds of different organic carbon compounds that are generally of primary anthropogenic origin (CEPA, 1999). The coarse fraction consists of materials that are common to the earth's crust such as oxides of iron, calcium, silicon, and aluminum and sea spray (sodium and chloride) (CEPA, 1999).

In evaluating potential health effects associated with inhalation of particulates, the particulate size is of importance. Ultrafine and fine particulate matter are of greatest concern to human health “because they can be transported long distances, penetrate indoors readily, reach deep into the lung, and are the particles most enriched in toxic compounds” (Committee on Health Effects of Waste Incineration, Board on Environmental Studies and Toxicology, Commission on Life Sciences, National Research Council, 2000). Facility-specific information regarding particulate size in the emissions from the proposed incinerator is not available.

Section 5 (Tables 5-7 and 5-8) of the Air Quality Assessment Report (Appendix N of the EIA) shows predicted 24-hour and annual ground level incremental concentrations of TSP. Results have been presented as stack TSP concentrations, IBA TSP concentrations, and total TSP concentrations. The highest predicted incremental concentrations for 24-hour and annual averages fall below the assessment criteria.

Although the background concentrations were not available for TSP near the Project area, the low predictions of GLCs indicate that the contribution to the air shed at the defined sensitive receptor from the proposed Project will be minimal.

The respirable portion of TSP, particles with diameters less than 10 µm (PM_{10}) and especially particles with aerodynamic diameters less than 2.5 µm ($PM_{2.5}$), pose the greatest health risk (Yang, 2016, VOL. 66, NO. 8) (World Health Organization, 2005) (US Environmental Protection Agency, Accessed October 4, 2018) because they can be inhaled deep into the lungs. The WHO established air quality guidelines for annual average and 24-hour mean PM_{10} and $PM_{2.5}$. These guidelines were established as targets that would allow for significant reductions in acute and chronic adverse health effects. The United States Environmental Protection Agency (USEPA) has annual National Ambient Air Quality Standard (NAAQS) for fine particulate matter ($PM_{2.5}$, i.e., particles smaller than 2.5 micrometres (µm) in aerodynamic diameter) to 12 micrograms per cubic metre (µg/m^3). The criteria for $PM_{2.5}$ was set to protect healthy and sensitive populations (e.g., pregnant women, people with preexisting conditions, obese population) against adverse health effects linked to acute and chronic PM exposure. Exposure to PM has been linked with adverse health outcomes (e.g., premature death, cardiovascular effects, and respiratory effects). The 24-hour health standard for $PM_{2.5}$ is 35 µg/m^3. Coarse particulate matter (PM10, i.e., particles between 2.5 and 10 µm in aerodynamic diameter) has been set at 150 µg/m^3.

Assuming a conservative ratio of 1:1 for TSP and PM_{10}, Section 5 (Tables 5-9 and 5-10) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 24-hour and annual GLCs for PM_{10}. The results in the tables have been presented as stack PM_{10} concentrations, IBA PM_{10} concentrations and total PM_{10} concentrations in order to give a greater understanding of the proportion of the PM_{10} being emitted from each source. The highest predicted incremental concentrations for 24-hour and annual averages fall below the assessment criteria.

When added to the adopted 24-hour PM_{10} and annual background concentration of 195 µg/m^3 and 157 µg/m^3, respectively, resulting concentrations at all sensitive receptors exceed the WHO criteria of 50 µg/m^3 and 20 µg/m^3, respectively. However, the incremental impact of the 24-hour and annual PM_{10} concentrations at the sensitive receptor location with the maximum concentrations (Pivot Fields) with dust controls are predicted to be less than 6% and 2%, respectively, of the WHO criteria, which is in compliance with the IFC suggestion of 25% of the applicable air quality standards to allow for additional, future sustainable development in the same airshed.

Assuming a conservative ratio of 1:1 for TSP to $PM_{2.5}$, Section 5 (Tables 5-11 and 5-12) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 24-hour and annual GLCs of $PM_{2.5}$. The highest predicted incremental concentrations for 24-hour and annual averages fall below the assessment criteria.

When the 24-hour $PM_{2.5}$ concentrations are added to the adopted background concentration of 63 µg/m^3, the resulting $PM_{2.5}$ concentrations at all sensitive receptors exceed the WHO criteria of 25 µg/m^3. However, the incremental impact of the 24-hour and annual $PM_{2.5}$ concentrations at the sensitive receptor location with the maximum concentrations (Pivot Fields) are predicted to be 6% and 2% of the WHO criteria without and with dust controls respectively. With dust control, the maximum total $PM_{2.5}$ concentrations are unchanged due to emissions from the stacks having a larger effect on ambient concentrations compared to the IBA-serving trucks. This is in compliance with the IFC suggestion of 25% of the applicable air quality standards to allow for additional, future sustainable development in the same airshed.

The health effects would be associated with the existing adopted background air concentrations. The small incremental increase in the ambient air concentration due to the modelled emissions for TSP, PM_{10}, and $PM_{2.5}$ from the WMC is not anticipated to result in a significant change to the air quality of the airshed or associated health effects. The highest TSP, PM_{10}, and $PM_{2.5}$ concentrations are associated with IBA without dust control for both 24-hour and annual concentrations with only a very small percentage from the stacks. The low predictions of GLCs indicate that the contribution to the air shed at the defined sensitive receptor from the proposed Project will be minimal.

7.1.5 Acid Gases (Hydrogen Chloride and Hydrogen Fluoride)

Corrosive burns may result from the inhalation of acid fumes and from skin contact with or the ingestion of strong acid. Symptoms after ingestion or skin contact include immediate pain and ulceration of all membranes and tissues which come in contact with the acid. Ingestion may be associated with nausea, vomiting and intense thirst; corrosion of the stomach may lead within a few hours or a few days to gastric perforation and peritonitis. Late esophageal, gastric and pyloric strictures and stenoses should be anticipated. Contact with concentrated acid with the eye can cause extensive necrosis of the conjunctiva and corneal epithelium, resulting in perforation or opaque scarring. Chemical pneumonitis can be expected after respiratory exposure to acid vapors or after tracheobronchial aspiration of ingested acid. Death may occur due to complications such as circulatory shock, asphyxia due to glottic or laryngeal edema, perforation of the stomach with peritonitis, gastric hemorrhage, infection or anition due to stricture formation (HSDB, 2014).

Section 5 (Table 5-13) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 99.9^{th} percentile 1-hour HCl and 24-hour HF GLCs. The highest predicted incremental concentrations are below the assessment criteria.

Although background concentrations were not available for HCl and HF near the Project area, the low predictions of GLCs indicate that the contribution to the air shed at the defined sensitive receptors from the proposed Project will be minimal.

Therefore, these modelled concentrations should not result in any adverse human health effects.

7.1.6 Dioxins/Furans (TCDD) and Ammonia

Chlorinated dibenzo-p-dioxins/furans (dioxins/furans) are a group of compounds (congeners) that exist as mixtures. Of all the dioxin/furan congeners, 2,3,7,8- Tetrachlorodibenzo-p-dioxin (TCDD) is the best studied, and is the reference compound for this group. Dioxins are combined to provide a single meta-parameter, 2,3,7,8-TCDD Toxic Equivalences (TEQs). The use of TEQs is widely accepted in the international scientific community and is commonly used in the evaluation of dioxins/furans. Emission factors from the WMC were not provided on a congener-specific basis, rather as a total 2,3,7,8-TCDD TEQ. Therefore, dioxin and furan emissions from the Project used in this HHRA were reported on a 2,3,7,8-TCDD TEQ basis. They represent the suite of dioxin and furan congeners that are used to assess the toxicity of these chemicals as a mixture.

Only a very low level of dioxin and furans would be expected in the municipal solid waste that is to be the feedstock material for the Facility. These chemicals are formed in the Facility as a result of incomplete combustion of organic material and will be emitted to the environment in low concentrations.

The primary and most immediate effect of ammonia exposure is due to its irritant and corrosive properties, which results in burns to the eyes, skin, and respiratory tract. The alkaline properties and high water solubility of ammonia allows it to dissolve in moisture on the mucous membranes, skin, and eyes forming ammonium hydroxide. Ammonium hydroxide causes liquefaction necrosis of the tissues (ATSDR, 2004). Airway blockage and respiratory insufficiency may result from exposure to anhydrous ammonia vapours or concentrated aerosols. Ingestion of concentrated solutions of ammonia may produce severe hemorrhage of the upper gastrointestinal tract in addition to severe burns.

Section 5 (Table 5-14) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 99.9th percentile 1-hour TCDD and NH_3 GLCs. The highest predicted incremental concentrations fall below the assessment criteria. Although the background concentrations were not available for TCDD and NH_3 near the Project area, the low predictions of GLCs indicate that the contribution to the air shed at the defined sensitive receptors from the proposed Project will be minimal. Therefore, these modelled concentrations should not result in any adverse human health effects.

7.1.7 Mercury (Hg) and Cadmium (Cd)

Respiratory, cardiovascular, gastrointestinal, hematological, neurological and renal effects have been observed in both humans and animals after acute-duration inhalation exposure to metallic mercury (ATSDR, 1999). Tremors, irritability, and decreased motor functions and reflexes were common neurological symptoms following high-level acute duration exposures to metallic mercury vapors. Short-term exposure to high levels of metallic mercury vapor can also damage the lining of the mouth and irritate the respiratory tract, causing tightness of the breath, burning sensation in the lungs and coughing. Other effects from mercury vapor exposure include nausea, vomiting, diarrhea, increase in blood pressure or heart rate, skin rashes, and eye irritation (ATSDR, 1999). Mercury has not been classified as a probable human carcinogen. The primary target organ for exposure to mercury via inhalation is the nervous system (USEPA, 1995).

Cadmium exposure, inhaled or ingested, can adversely impact the kidneys, respiratory system, and skeletal structure in humans (WHO, 2010). Cadmium is also a known human carcinogen. The kidneys are the primary target organ associated with chronic exposure to Cd since it accumulates in the kidneys and is not readily excreted. Acute exposure to high levels of inhaled Cd can result in death within days of exposure; although, the instances of death due to high-dose exposure are associated with occupational exposure in industries involved with heavy metals (WHO, 2005) (ATSDR, 2012).

Section 5 (Table 5-15) of the Air Quality Assessment Report (Appendix N of the EIA) shows the predicted 99.9th percentile 1-hour Hg and Cd ground level concentrations. While the highest predicted incremental concentrations for Hg are below the assessment criteria, the highest predicted incremental concentration for Cd is 0.025 $\mu g/m^3$ at the grid maximum, which exceeds the NSW AMMAAP criteria of 0.018 $\mu g/m^3$. It should be noted that the grid maximum occurred along the North West perimeter of the Project site, and not at a sensitive receptor location.

Although background concentrations were not available for Hg near the Project area, the low predictions of GLCs indicate that the contribution to the air shed at the defined sensitive receptors from the proposed Project will be minimal.

Predicted incremental concentrations at the three sensitive receptors (i.e. Desert Palm Riding School, Residential Villas, and Pivot Fields) exceeded the NSW AMMAAP Cd criteria, with concentrations of 0.02 $\mu g/m^3$, 0.0197 $\mu g/m^3$, and 0.0192 $\mu g/m^3$ respectively..

For Cd, the regulatory maximum emission rate from the IED was used in the modelling. This is a conservative approach and it is considered unlikely that emission in reality would reach this limit. Therefore, it is expected that the contribution of Cd to the air shed would be lower in reality.

It is noteworthy that expected Cd levels in MSW are expected to be relatively low and therefore, emission rates of the pollutant would not reach the levels demonstrated in this assessment (the regulatory limit of 0.05 mg/Nm^3). Therefore, the expected maximum concentration in reality would be significantly lower.

However, grid maximum estimate of the 1-hour for Cd air concentration, as presented in **Error! Reference source not found.**, are below published acute inhalation exposure guidelines. Acute inhalation exposure guidelines were developed for 1 to 14 days exposure duration, therefore comparison to an one hour average is conservative. Therefore, these modelled concentrations should not result in any adverse human health effects. For Cd, the regulatory maximum emission rate was used in the modelling which is a conservative approach and it is considered unlikely that emissions in reality would reach this limit. Therefore it is expected that the contribution of Cd to the air shed would be lower in reality

Table 2 Cadmium Comparison

Exposure average duration	Maximum estimated Cadmium air concentration (µg/m^3)	Comparison standard or guideline (µg/m^3)	
		New South Wales AMMAAP	ATSDR Minimal risk level – acute
1-hour exposure	0.025	0.018	0.03

7.2 Ingestion

Ingestion of the contaminants associated with emissions from the WMC could occur through deposition of these materials on food, water, food crops, or animal feed. Dioxins/furans in particular bioaccumulate in the food chain potentially leading to adverse human health impacts if dioxin-contaminated food is consumed.

Food crops and animal farms are not located within the study area. Consequently, bioaccumulation of contaminants through food production and plant or animals for human consumption, is not likely. Warsan Lake was identified as one of the sensitive receptor locations, so there is potential that deposition on to the lake and surrounding habitat may impact the soil and sediments. Therefore, bioaccumulation up the food chain for the ecological receptors living within Warsan Lake and surrounding habitat may occur but these ecological receptors will not be used for human consumption.

7.3 Dermal contact

Dermal contact with the contaminants in the vapour or particulate phase that will be emitted from the Facility are not anticipated to result in adverse human health effects due to low concentrations in the emissions.

8. Conclusions

For this Human Health Risk Assessment (HHRA) report, a review of potential health impacts associated with the proposed WMC has been undertaken. This review was based on available literature and air emission estimates specifically for this project.

The majority of the predicted incremental GLCs for the pollutants assessed are below the adopted assessment criteria, based on the stack characteristics and emission rates assumed for the Project. Therefore, these modelled air concentration should not result in an adverse effect to human health for the sensitive receptors via the inhalation exposure pathway.

The maximum predicted 1-hour NO_2 concentration at a defined sensitive receptor exceeded the WHO criterion when added to the adopted background concentrations. However, a conservative conversion rate for NOx to NO_2 was assumed (80%), which in reality is likely to be much lower.

Similarly, the cumulative concentration for PM_{10} and $PM_{2.5}$ exceeds the WHO criteria when background concentrations are considered. Again, the contribution of the WMC to PM_{10} and $PM_{2.5}$ concentrations are less than the 25% of the criteria, showing compliance with the IFC guideline. The health effects would be associated with the existing adopted background air concentrations. The small incremental increase in the ambient air concentration due to the modelled emissions from the WMC are not anticipated to result in a significant change to the air quality of the airshed or associated health effects.

The highest predicted maximum for Cd exceed the criteria at grid maximum and three of the sensitive receptor locations. However, the predicted concentrations at the sensitive receptor locations were below the acute ATSDR MRL. It should be noted that the maximum emission rate used in the model demonstrates a worst case scenario and it is understood that emission rates are likely to be lower in reality.

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		Name	Signature	Name	Signature	Date
Rev 0	A Gowing	D Wright	DW	S Bin Breik	SBB	12 Nov 2018
Rev 1	A Gowing	D Wright	DW	S Bin Breik	SBB	20 Dec 2018
Rev 2	A Gowing	D Wright	DW	S Bin Breik	SBB	Jun 2019
Rev 3	J Calpo	D Wright		R Shine		02 Oct 2019

Appendix S – Product Specification: Mobile Waste Shredder

URRACO 75

The Two Shaft Shredder

MATURE – **SUPERIOR** –

URRACO

LINDNER
we reduce it.
Mobile Shredder

THE URRACO 75

THE TWO SHAFT SHREDDER FOR ALMOST ANY MATERIAL

This is what LINDNER MOBILE SHREDDER stands for:

- Mature machinery concept
- High quality and durability due to first-class brand name components
- Innovative engineering and control technology
- Modular design for your individual requirements
- Continuous optimization and development of shredding shafts

The advantages of the Urraco 75

- Aggressive intake
- High throughput capacity of up to 60 tons per hour at low energy consumption
- High tolerance of foreign objects
- Low cost for wear and tear due to high durability and high quality components
- Service- and maintenance-friendly
- Low dust formation
- Fracture protection by reversing function
- High operational efficiency
- Multi-purpose applicability
- High shredding quality
- Defined output sizes due to adaptable shaft configurations
- Efficient energy stop for saving diesel fuel
- Effective cooling system

WOOD WASTE A1 – A4
Demolition wood, pallets, chipboard, cable drums, railway sleepers

BIOMASS
Green waste, rootstock, log wood, palms, animal manure, silo bales, grass cuttings

WASTE
Domestic waste, organic waste, plastics, PVC

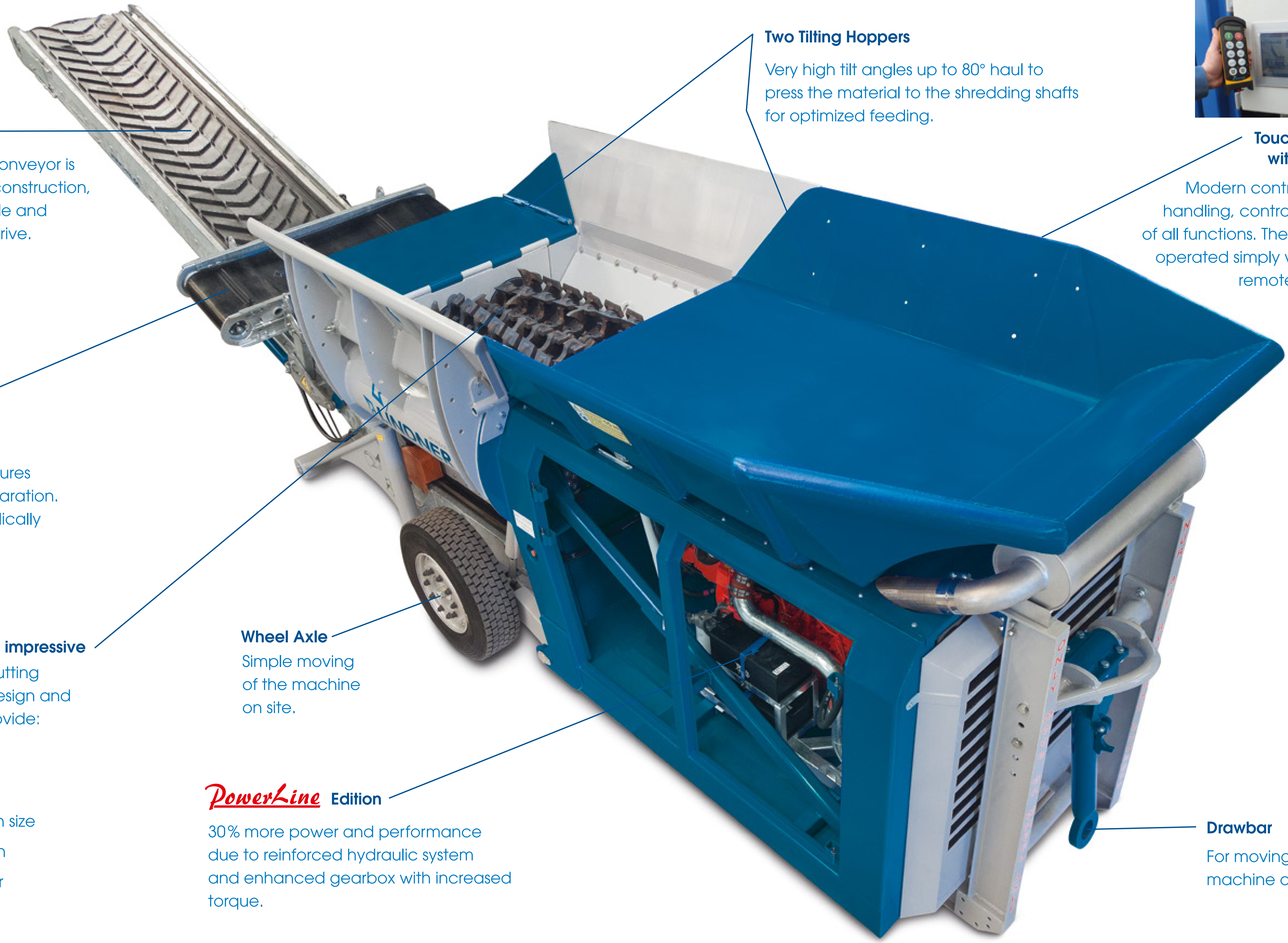
COMMERCIAL WASTE
Bulky waste, C&D waste, paper rolls, tar boards, mixed construction waste

METAL- & LIGHT SCRAP
electric and electronic scrap, alu scrap and alu housings

TIRES
Passenger car-, truck- and tractor-tires

Touch-Screen-Display with Remote Control

Modern control technology for handling, controls and monitoring of all functions. The machine can be operated simply with a 10-channel remote control from the loading machine



Discharge Conveyor

The frame of the discharge conveyor is made of a galvanized steel construction, hydraulically height adjustable and impresses with a strong belt drive.

Two Tilting Hoppers

Very high tilt angles up to 80° haul to press the material to the shredding shafts for optimized feeding.

Over-belt magnet

The powerful magnet with Extended magnetic core ensures a very high degree of Fe-Separation. The effective range is hydraulically adjustable.

LINDNER Shredding Shafts are impressive

The innovative and unique cutting geometry, the extra strong design and the rolling cutting process provide:

- Aggressive material intake
- High throughput capacity
- Fine and uniform final grain size
- Lower energy consumption
- Low cost for wear and tear

Wheel Axle

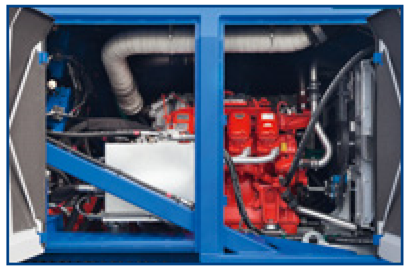
Simple moving of the machine on site.

PowerLine Edition

30% more power and performance due to reinforced hydraulic system and enhanced gearbox with increased torque.

Drawbar

For moving the machine on site.



Diesel Drive (D)

Powerful and economic standard engine, mounted on hook lift, for all medium and heavy primary shredding operations.

Scan QR-Code to see the URRACO Diesel in action.

Diesel Track System (DK)

Mounted on track system for deployment in rough terrain and controlled with 21-channel remote control.

Scan QR-Code to see the URRACO Diesel Track System in action.

Electric Drive (E)

Model for stationary operations in workshops and central locations, for more economy and environment-friendly applications.

Scan QR-Code to see the URRACO Electric Drive in action.

Further options

Environment-friendly Diesel engine with up-to-date emission standard 4/Tier F and 3B/Tier 4i. Low fuel consumption, low noise and energy-saving.

Special shafts for special applications

Water sprinkler system for dust collection

Over-belt magnet

Wheel axle with drawbar

Special colors

After-cutting comb

LW-Shafts

The specialist for the fine grain

- Wood waste A1 – A2
- Biomass
- Green waste
- Logs
- Rootstock
- Domestic waste
- Tires
- Paper rolls
- Tar board
- Plastics

Final grain: approx. 150 mm – 200 mm
4-fold fracture- and cutting-process in one shaft rotation

HW-Shafts

The specialist for the rough stuff

- Wood waste A1 – A4
- Rootstock
- Domestic waste
- Bulky waste
- C & D waste
- FE Light scrap
- Alu Light scrap
- Electronic scrap
- Railway sleepers
- Cable drums

Final grain: approx. 200 mm – 500 mm
Single fracture- and cutting-process in one shaft rotation

The Two Shaft Shredder

URRACO 75

The most powerful two shaft shredder in its class.
The ideal primary shredder for almost any material.
The Urraco impresses with the aggressive intake, robust construction, quality, cost effectiveness, service-friendliness, performance and durability.

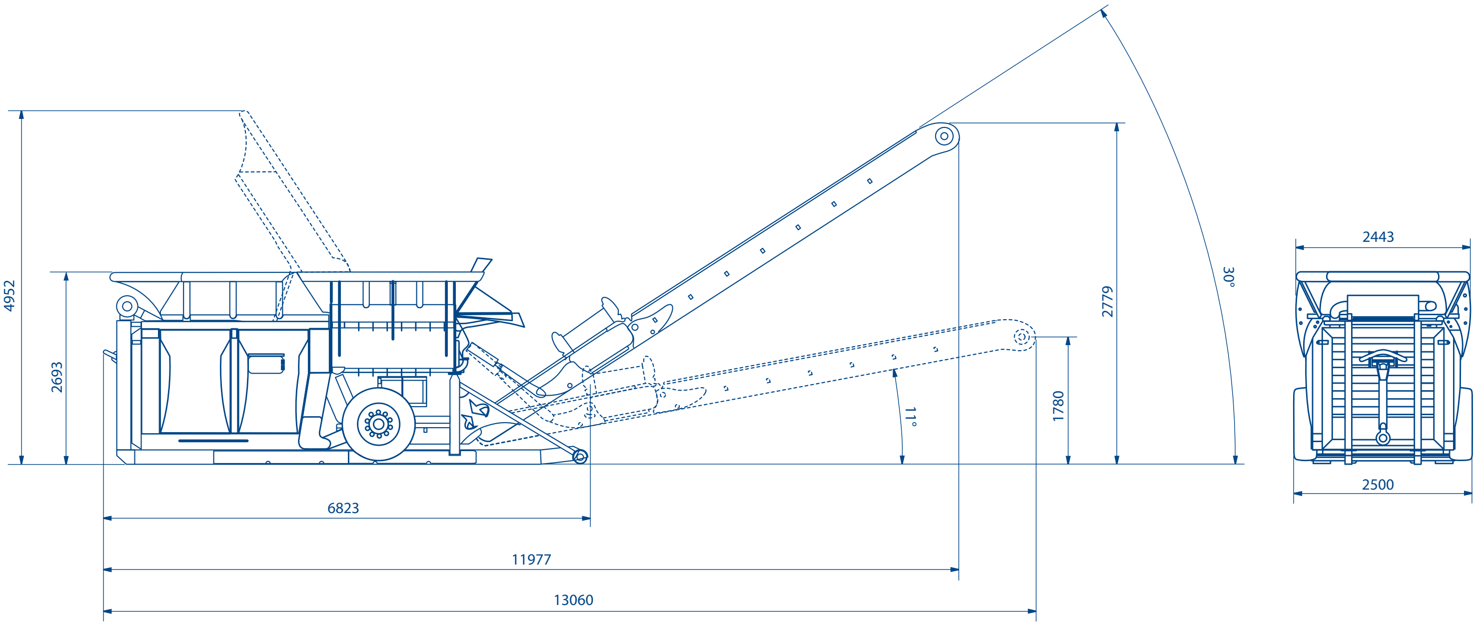
Lindner Mobile Shredders URRACO 75 is universally applicable in any mobile, semi-mobile and stationary sector.

TECHNICAL DATA	URRACO 75 D/E	URRACO 75 D/E PowerLine
Drive power diesel	350 PS	350 PS
Drive power electric	250 kW	250 kW
Shredding shaft length	1750 mm	1750 mm
Shredding shaft diameter	650 mm	650 mm
Weight machine	17 t	17 t
Weight magnet	1 t	1 t
Weight track system	4 t	4 t
Dimensions (L x B x H)	7,0 m x 2,5 m x 2,7 m	7,0 m x 2,5 m x 2,7 m

CAPACITY AT*	URRACO 75 D/E	URRACO 75 D/E PowerLine
Wood waste	up to 45 t/h	up to 60 t/h
Domestic waste	up to 50 t/h	up to 65 t/h
Bulky and C & D waste	up to 25 t/h	up to 40 t/h
Biomass	up to 150 m³/h	up to 200 m³/h

* Standard data and throughput capacities may vary depending on tools, feeding, specific weights and densities as well as properties of material.

Update: May 2014. Technical changes, misprints and errors reserved. All images are sample pictures. All specifications are approximate.



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we reduce it.
LINDNER
Mobile Shredder