

5.6.3 The requirement for biogas monitoring during the operational phase of the development should be established based on the detailed design of the development and the borehole monitoring results. Consultation with EPD to set up the requirement would be necessary.

5.7 Limit Levels and Action Plan for Biogas Monitoring

5.7.1 Table 5.1 summarises the limit levels and action plan for biogas monitoring during construction.

Table 5.1 Limit Levels and Action Plan for Biogas Monitoring during Construction Phase

Parameter	Limit Level	Action
Methane	> 0.5% v/v (or > 10% LEL)	<ol style="list-style-type: none"> 1. Prohibit smoking, all fires and naked flames. 2. Post warning signs. 3. Increase ventilation to lower the methane level to less than 0.5% v/v.
	> 1% v/v (or > 20% LEL)	<ol style="list-style-type: none"> 1. Stop all the construction activities in the affected area. 2. Evacuate personnel who are working in the affected area. 3. Prohibit entry to the affected area. 4. Increase ventilation to lower the methane level to less than 0.5% v/v.
Carbon Dioxide	> 0.5% v/v	<ol style="list-style-type: none"> 1. Increase ventilation to lower the carbon dioxide level to less than 0.5% v/v.
	> 1.5 % v/v	<ol style="list-style-type: none"> 1. Extinguish all fires and naked flames. 2. Stop all the construction works in the affected area. 3. Evacuate personnel in the affected area. 4. Prohibit entry to the affected area. 5. Increase ventilation to lower the carbon dioxide level to less than 0.5% v/v.
Oxygen	≤ 18% v/v	<ol style="list-style-type: none"> 1. Stop all the construction activities in the affected area. 2. Evacuate personnel in the affected area. 3. Prohibit entry to the affected area. 4. Increase ventilation to increase the oxygen level to above 18% v/v.

5.8 Biogas Mitigation Measures

5.8.1 Mitigation measures for control of biogas would be required for no dredged reclamation and minimum dredged reclamation. The recommended environmental mitigation measures for the sediment treatment are presented in **Appendix A** of the EM&A Manual and the provision therein would be properly enforced. Relevant mitigation measures are also detailed as follows:

No Dredged Reclamation

No Sediment Treatment

5.8.2 Precaution measures for construction site:

- Provision of safety measures for works to be carried out in confined space;
- Monitoring of the methane, carbon dioxide and oxygen levels in excavated areas and areas below ground;
- Provision of adequate ventilation in temporary structures;
- No smoking and open fire in region where drilling activities are carried out; and
- Provision of vent pipes to collect and vent off the accumulated methane gas to atmosphere should high methane concentrations be detected.

5.8.3 Methane gas monitoring should be included as part of the EM&A programme for the development. Installation of monitoring boreholes would be required to monitor the actual methane emission rate.

5.8.4 Recommendations on implementation of protection measures include:

- Protection measures are required for the measured methane emission rates consistently higher than the maximum safe rate of gas emission (i.e. 10L/m²/d);
- Protection measures may not be required for the measured methane emission rates consistently below the maximum safe rate of gas emission (i.e. 10L/m²/d); and
- Continuous monitoring would be required for the measured methane emission rates occasionally exceed the maximum safe rate of gas emission (i.e. 10L/m²/d).

5.8.5 Some of the most commonly used protection measures to prevent methane hazards include:

- Provision of control systems in the ground and beneath/inside the building floor to collect and vent off the methane gas generated underneath the reclaimed land;
- Use of a porous fill material to allow the migration of methane gas from underground to the surface of the fill material;
- Installation of a gas collection layer consisting of gravels to serve as a primary control of methane gas emission;
- Provision of vent trenches filled with gravels or “no fines” crushed aggregates of uniform size at perimeter of the reclamation area;
- Connecting the vent trenches to the gas collection layer to provide a route to vent off the collected methane gas;
- Use of finalised development layouts for the design and installation of the piping collection network;
- Installation of low gas permeability sealant to prevent penetration of methane gas into buildings through below ground services;
- Installation of low permeability physical barriers to prevent the migration of methane gas from entering the buildings;
- Installation of a membrane with low gas permeability in the floor slab of buildings including underground car parks and rooms to prevent ingress of methane gas;
- Sealing of any openings in the floor;
- Provision of sufficient ventilation within buildings to avoid accumulation of methane gas to a dangerous level;
- Installation of passive barriers to prevent gases from entering the buildings by installing low-permeability geomembranes;
- Installation of passive ventilation systems to provide a route for the sub-slab gases to escape to the atmosphere through the voids below the building slabs; and
- Protection measures should be included in the specification for construction and be incorporated into the design, tender and construction stages of the development.

In-situ Sediment Treatment

5.8.6 Precaution measures for construction site:

- Provision of safety measures for works to be carried out in confined space;
- Monitoring of the methane, carbon dioxide and oxygen levels in excavated areas and areas below ground;
- Provision of adequate ventilation in temporary structures;
- No smoking, fire and naked flame in region where drilling activities are carried out; and
- Provision of vent pipes to collect and vent off the accumulated methane gas to atmosphere should high methane concentrations be detected.

5.8.7 Methane gas monitoring should be included as part of the EM&A programme for the development. Installation of monitoring boreholes would be required to monitor the actual methane emission rate.

5.8.8 Protection measures to prevent the methane hazards, if necessary, would be similar to those for the no treatment approach. Recommendations on implementation of protection measures are as follows:

- Protection measures are required for the measured methane emission rates consistently higher than the maximum safe rate of gas emission (i.e. 10L/m²/d);
- Protection measures may not be required for the measured methane emission rates consistently below the maximum safe rate of gas emission (i.e. 10L/m²/d); and
- Continuous monitoring would be required for the measured methane emission rates occasionally exceed the maximum safe rate of gas emission (i.e. 10L/m²/d).

5.8.9 Some of the most commonly used protection measures to prevent methane hazards include:

- Provision of control systems in the ground and beneath/inside the building floor to collect and vent off the methane gas generated underneath the reclaimed land;
- Use of a porous fill material to allow the migration of methane gas from underground to the surface of the fill material;
- Installation of a gas collection layer consisting of gravels to serve as a primary control of methane gas emission;
- Provision of vent trenches filled with gravels or “no fines” crushed aggregates of uniform size at perimeter of the reclamation area;
- Connecting the vent trenches to the gas collection layer to provide a route to vent off the collected methane gas;
- Use of finalised development layouts for the design and installation of the piping collection network;
- Installation of low gas permeability sealant to prevent penetration of methane gas into buildings through below ground services;
- Installation of low permeability physical barriers to prevent the migration of methane gas from entering the buildings;
- Installation of a membrane with low gas permeability in the floor slab of buildings including underground car parks and rooms to prevent ingress of methane gas;
- Sealing of any openings in the floor;
- Provision of sufficient ventilation within buildings to avoid accumulation of methane gas to a dangerous level;
- Installation of passive barriers to prevent gases from entering the buildings by installing low-permeability geomembranes;
- Installation of passive ventilation systems to provide a route for the sub-slab gases to escape to the atmosphere through the voids below the building slabs; and
- Protection measures should be included in the specification for construction and be incorporated into the design, tender and construction stages of the development.

Minimum Dredged Reclamation

5.8.10 The minimum dredged reclamation is basically the same as the no dredged reclamation except for the dredging in the temporary/permanent sea wall location. Precaution and protection measures are the same as those for the no dredged reclamation.

No Sediment Treatment of the Remaining Sediments

5.8.11 Precaution measures for construction site:

- Provision of safety measures for works to be carried out in confined space;

- Monitoring of the methane, carbon dioxide and oxygen levels in excavated areas and areas below ground;
- Provision of adequate ventilation in temporary structures;
- No smoking and open fire in region where drilling activities are carried out; and
- Provision of vent pipes to collect and vent off the accumulated methane gas to atmosphere should high methane concentrations be detected.

5.8.12 Methane gas monitoring should be included as part of the EM&A programme for the development. Installation of monitoring boreholes would be required to monitor the actual methane emission rate.

5.8.13 Recommendations on implementation of protection measures include:

- Protection measures are required for the measured methane emission rates consistently higher than the maximum safe rate of gas emission (i.e. 10L/m²/d);
- Protection measures may not be required for the measured methane emission rates consistently below the maximum safe rate of gas emission (i.e. 10L/m²/d); and
- Continuous monitoring would be required for the measured methane emission rates occasionally exceed the maximum safe rate of gas emission (i.e. 10L/m²/d).

5.8.14 Some of the most commonly used protection measures to prevent methane hazards include:

- Provision of control systems in the ground and beneath/inside the building floor to collect and vent off the methane gas generated underneath the reclaimed land;
- Use of a porous fill material to allow the migration of methane gas from underground to the surface of the fill material;
- Installation of a gas collection layer consisting of gravels to serve as a primary control of methane gas emission;
- Provision of vent trenches filled with gravels or “no fines” crushed aggregates of uniform size at perimeter of the reclamation area;
- Connecting the vent trenches to the gas collection layer to provide a route to vent off the collected methane gas;
- Use of finalised development layouts for the design and installation of the piping collection network;
- Installation of low gas permeability sealant to prevent penetration of methane gas into buildings through below ground services;
- Installation of low permeability physical barriers to prevent the migration of methane gas from entering the buildings;
- Installation of a membrane with low gas permeability in the floor slab of buildings including underground car parks and rooms to prevent ingress of methane gas;
- Sealing of any openings in the floor;
- Provision of sufficient ventilation within buildings to avoid accumulation of methane gas to a dangerous level;
- Installation of passive barriers to prevent gases from entering the buildings by installing low-permeability geomembranes;
- Installation of passive ventilation systems to provide a route for the sub-slab gases to escape to the atmosphere through the voids below the building slabs; and
- Protection measures should be included in the specification for construction and be incorporated into the design, tender and construction stages of the development.

In-situ Sediment Treatment of the Remaining Sediments

5.8.15 Precaution measures for construction site:

- Provision of safety measures for works to be carried out in confined space;

- Monitoring of the methane, carbon dioxide and oxygen levels in excavated areas and areas below ground;
- Provision of adequate ventilation in temporary structures;
- No smoking, fire and naked flame in region where drilling activities are carried out; and
- Provision of vent pipes to collect and vent off the accumulated methane gas to atmosphere should high methane concentrations be detected.

5.8.16 Methane gas monitoring should be included as part of the EM&A programme for the development. Installation of monitoring boreholes would be required to monitor the actual methane emission rate.

5.8.17 Protection measures to prevent the methane hazards, if necessary, would be similar to those for the no treatment approach. Recommendations on implementation of protection measures include:

- Protection measures are required for the measured methane emission rates consistently higher than the maximum safe rate of gas emission (i.e. 10L/m²/d);
- Protection measures may not be required for the measured methane emission rates consistently below the maximum safe rate of gas emission (i.e. 10L/m²/d); and
- Continuous monitoring would be required for the measured methane emission rates occasionally exceed the maximum safe rate of gas emission (i.e. 10L/m²/d).

5.8.18 Some of the most commonly used protection measures to prevent methane hazards include:

- Provision of control systems in the ground and beneath/inside the building floor to collect and vent off the methane gas generated underneath the reclaimed land;
- Use of a porous fill material to allow the migration of methane gas from underground to the surface of the fill material;
- Installation of a gas collection layer consisting of gravels to serve as a primary control of methane gas emission;
- Provision of vent trenches filled with gravels or “no fines” crushed aggregates of uniform size at perimeter of the reclamation area;
- Connecting the vent trenches to the gas collection layer to provide a route to vent off the collected methane gas;
- Use of finalised development layouts for the design and installation of the piping collection network;
- Installation of low gas permeability sealant to prevent penetration of methane gas into buildings through below ground services;
- Installation of low permeability physical barriers to prevent the migration of methane gas from entering the buildings;
- Installation of a membrane with low gas permeability in the floor slab of buildings including underground car parks and rooms to prevent ingress of methane gas;
- Sealing of any openings in the floor;
- Provision of sufficient ventilation within buildings to avoid accumulation of methane gas to a dangerous level;
- Installation of passive barriers to prevent gases from entering the buildings by installing low-permeability geomembranes;
- Installation of passive ventilation systems to provide a route for the sub-slab gases to escape to the atmosphere through the voids below the building slabs; and
- Protection measures should be included in the specification for construction and be incorporated into the design, tender and construction stages of the development.

Pilot Tests

5.8.19 The feasibility of *in-situ* treatment and *ex-situ* treatment should be demonstrated through pilot tests, which would include bench scale laboratory tests and field trials. The recommended *in-situ* treatment methods or reagents for sediment remediation in the SEKD include:

- Fenton's Reagent;
- Oxygen Release Compound (ORC); and
- Seditreat™.

The recommended *ex-situ* treatment methods are:

- BioGenesis Sediment Washing; and
- Daramend™ Bioremediation.

5.8.20 Bench scale laboratory tests will examine the treatability of sediments by the *in-situ* and *ex-situ* treatment methods. The results obtained from the bench scale tests will be used for evaluation of the suitable methods/oxidants and formulation of the subsequent site trials.

Fall Back Option

- Should the pilot tests indicate that both the *in-situ* treatment and *ex-situ* treatment fail to reduce the methane potential of the KTAC sediments to an acceptable level, use of protection measures to collect and vent off the methane gas in the locations with high methane potential would be adopted as a fall back option;
- Monitoring of methane gas emission rate in the KTAC should be carried out to identify the hot spots with high emission rate;
- Protection measures should be provided to safeguard the individual developments in that particular area where exceedance of the maximum safe rate of gas emission is constantly detected, and also be provided in areas where maximum safe rate of gas emission is occasionally exceeded and with an increasing trend of the methane flow rate;
- As methane gas may accumulate in below ground services, use of air-tight sockets for electricity supply system would be one of the measures to prevent ingress of methane gas from below ground conduits.