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Innovative and practical environmental technologies in the construction industry for sustainability enhancement

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ABSTRACT

To mitigate climate change and global warming, over 180 countries signed the Paris Agreement to keep the global average temperature no more than 2°C above pre-industrial levels and to aim for the increment to be below 1.5°C. In Hong Kong, the Environmental Protection Department sets the target for reducing carbon dioxide emissions per capita to 3.8 tonnes in 2030 and continues to strive to achieve carbon neutrality before 2050. The construction industry accounts for 36% of total energy usage and 40% of total carbon emissions, and it plays a significant role in sustainability. To enhance sustainability, innovative technologies are adopted for the reduction of energy consumption and fostering environmental friendliness. In this study, different innovative and practical environmental technologies for use in the construction industry are summarised including the venturi cyclone, dewatering bag system, and deodorising sewage tank. It shows that the adoption of innovative technologies is capable of bolstering a friendly working environment and achieving sustainability. This paper is aimed to promote different innovative environmental technologies and encourage the construction industry to spare no effort in utilising new technologies for better sustainability.

KEYWORDS Sustainability; construction; innovation; environment
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Received 3 August 2023

1. Introduction

Electricity consumption was responsible for 66% of the carbon emissions in Hong Kong in 2019. The construction industry consumes 36% of the total energy usage and is associated with 40% of the total carbon emission. These percentages show that the construction industry is one of the major sectors contributing to the overall energy consumption. To strive to achieve carbon neutrality by 2050, different milestones in 2035 are set for net-zero electricity generation and energy saving. Milestones include ceasing to use coal for daily electricity generation by migrating to using low to zero carbon energy sources, attempting to adopt new energy sources, cooperating closely with neighbouring areas to increase zero-carbon electricity generation, and looking for investment in, and the development opportunities of, innovation projects related to zero-carbon energy near Hong Kong (Carbon Neutrality@HK, 2021).

Many emerging technologies have been utilised for energy saving and sustainability in built environments, and designated projects have been launched, for example, the district cooling system in Kai Tak Development and other new development areas (Cheng, 2020). It is found that the use of the district cooling system in Kai Tak Development can reduce the energy consumption by 85 million kWh, which equates to a 35% saving versus the air-cooled system of conventional cooling towers, and is equivalent to 59,500 tonnes of carbon emission reduction. Yau et al.(2014) reported an energy cascade used for cooling, heating, and power systems in Zero Carbon Buildings in Hong Kong. The results reveal that 70% of the fuel energy can be captured by the energy cascade, while only 30% of the conventional electricity supply can be captured because using fuel energy generates more waste heat which can be utilised for energy recovery. Apart from the substantial carbon emission problem, the construction industry is confronting immense challenges such as unpleasant work environment, engendering pollution, deterring new workforce, stagnant productivity growth, and cost escalation.

To overcome these challenges, sustainability is an indispensable element in the construction industry. Sustainable construction targets to reduce the impact on environmental, social, and economic aspects induced by the construction process. There are different measures to achieve sustainable construction and yield additional benefits, namely green financing, the utilisation of low-carbon materials and equipment, construction waste sorting and management, innovative technologies such as Design for Manufacture and Assembly (DfMA), and Building Information Modelling (BIM). However, there are insufficient well-tested innovative and practical technologies for decarbonisation and sustainability in the construction industry in Hong Kong. The authors' organisation, as a pioneer and innovator in the construction industry, investigated and successfully developed a few innovative environmental technologies and conducted pilot and field tests to study the feasibility of applications in actual construction site environments. In this paper, a comprehensive case study is presented to showcase the innovative and practical environmental technologies including venturi cyclones, dewatering bag systems, and deodorising sewage tanks, where the research and development activities were completed in-house by cross-disciplinary departments within the organisation. It is anticipated that the decarbonisation and sustainability in the construction industry can be promoted by the innovations, which would stimulate stakeholders in the construction industry to devote more effort to the decarbonisation and sustainability to not only overcome problems in the short term but also create a better living environment in the long term.

Hereunder, three innovative and practical environmental technologies are presented and demonstrated: 1) venturi cyclones, 2) dewatering bag systems, and 3) deodorising sewage tanks.

2. Venturi cyclone

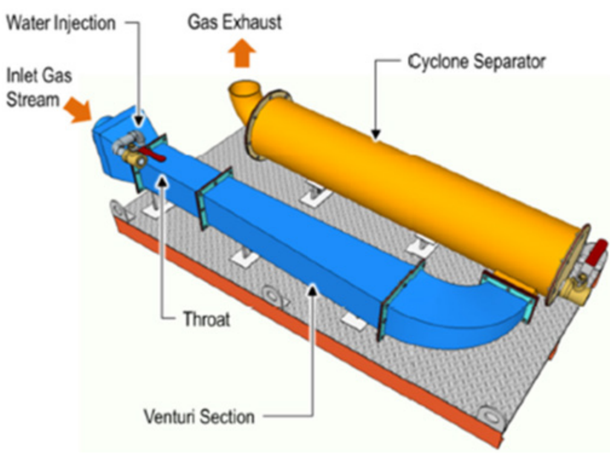
Diesel generators are widely used on construction sites for electricity generation because some of the construction sites are located in remote and off-grid areas. However, the diesel generators incur high operational and maintenance costs (Tazvinga et al., 2014) as well as resulting in environmental issues, such as air pollutant emission (Ghasemi et al., 2013), high carbon emission due to low energy efficiency (Mobarra et al., 2022), and noise nuisance (Farhan et al., 2021). These issues lead to an unsatisfactory workplace environment for the construction personnel and hinder more and more people from getting into the construction industry. To remedy the issues, the venturi cyclone was invented as an accessory for diesel generators to remove air pollutants, reduce carbon emissions, and lessen the noise level.

Figure 1(a) presents the schematic design of the venturi cyclone. There are two major sections, i.e., venturi section and cyclone separator. With respect to the venturi section, the diesel generator's exhaust pipe is connected to the inlet of the venturi section by either a metal pipework or a heat-resistant flexible pipe capable of sustaining a gas temperature of 800°C. Water droplets are injected at the upstream region of the "throat" of the venturi section where the throat is a narrowed channel creating the venturi effect for accelerating the water droplets to be atomised. The venturi effect indicates that the velocity of the fluid is inversely proportional to the cross-sectional area of the channel because of the constant volumetric flow rate along the axial direction, which is equal to the velocity of the fluid multiplied by the cross-sectional area. After the throat section, the tiny water droplets can capture the pollutants at the entrance of the diverging section. Subsequently, the tiny water droplets coagulate with each other to become larger at a smaller air flow rate due to the widening area of the diverging section for deceleration, as illustrated in Figure 1(c). Thus, the chance of water droplet coagulation is augmented. When the water droplets coalesce to attain the designed size, the water droplets enter into the cyclone separator via an L-shaped converging elbow, where the area is tapered to provide an increasing tangential velocity, as shown in Figure 1(d).

A cyclone separator is conventionally used for removing particles or droplets from the air. The induced centrifugal force is tangentially exerted on the droplets. In the case of large droplets, when the induced centrifugal force exceeds a certain value coincidental to the increasing air velocity and the decreasing radius of the cyclone, the large droplets are collected by the wall of the cyclone separator through inertia impaction. The collected large droplets with contaminants then settle at the bottom of the cyclone separator due to the slightly tilted tube, and the settled water is drained off into the oil trap for collection and subsequent treatment. The small droplets move along the streamline and exhaust at the cyclone outlet into the ambient environment. In the oil trap, the oily substances are removed by a belt skimmer, which is attached to the oil trap in order to lift the floating oils from the surface of wastewater, and are delivered to a container for storage.

It is worth noting that the removed oily substances are the mixtures containing unburnt carbon cores, hydrocarbons, sulphates, etc. which are pollutants in the diesel exhaust and required to be handled cautiously as chemical waste and processed by licensed collectors. Subsequently, the residual wastewater in the oil trap is free of oils, containing captured pollutants, such as diesel particulate matter and absorbed gaseous pollutants (e.g. NO_x, SO_2, CO_2, etc.) and the residual wastewater is diverted to a small on-site wastewater treatment plant which can effectively remove the particulates via chemically enhanced coagulation and flocculation, and the acidic wastewater is neutralised to within the range of the legitimate pH value. The treated wastewater is circulated into the oil trap again and then injected into the throat section for atomisation to complete the cycle. The detailed schematic diagrams of the oil trap and the belt skimmer are shown in Figures 1(e) and 1(f). The employment of the venturi cyclone is not only able to mitigate the diesel exhaust of generators but also fully utilise the water resources since the wastewater in construction sites is normally alkaline due to the presence of waste cement. The alkaline wastewater can be used for neutralisation of the acidic wastewater in the venturi cyclone which helps to reduce the operation cost and resource deployment (i.e., acid consumption). It should be noted that there are different capacities of the diesel generators in various construction sites. The dimensions of the throat and rectangular orifice plate at the inlet of the cyclone separator are well designed to fit different diesel generator models so that the throat and inlet of the cyclone separator are replaceable subject to the dimensions of diesel generators.

(a)



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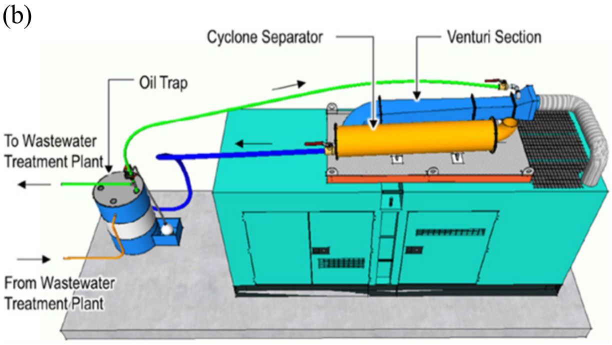

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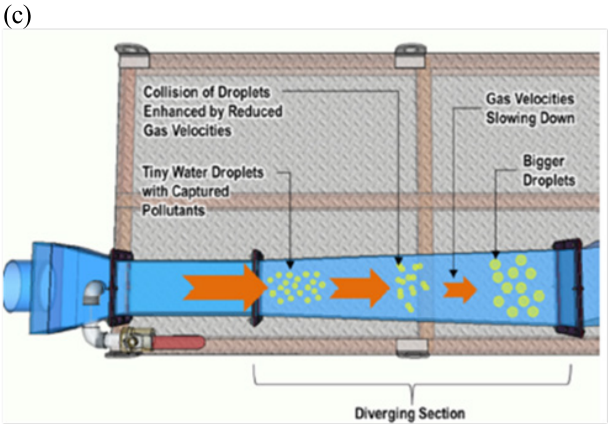

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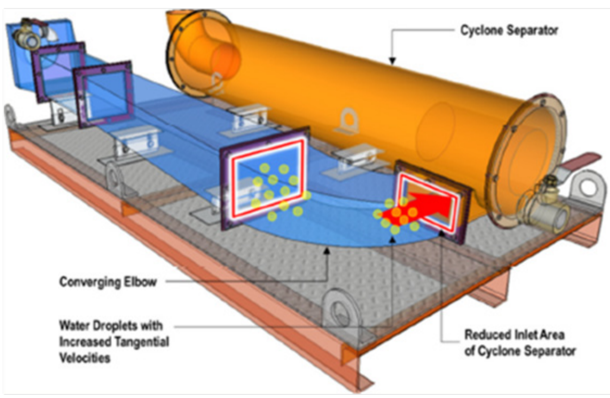

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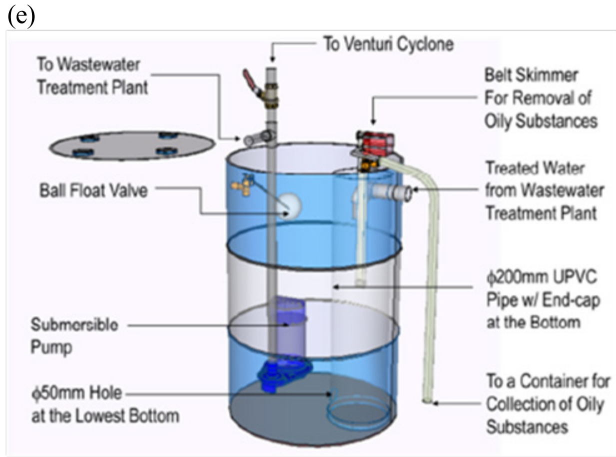

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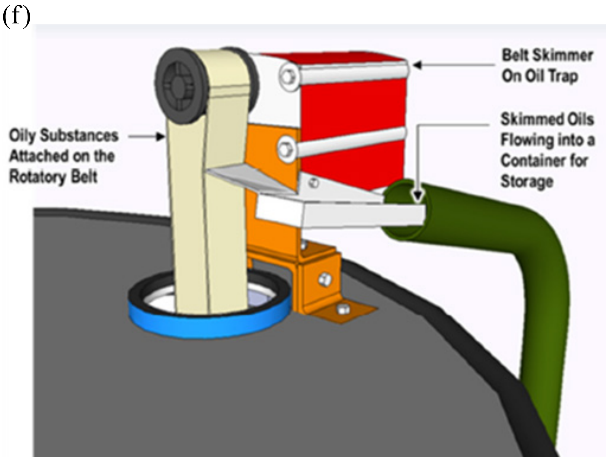


Figure 1. (a) Design of the venturi cyclone; (b) diesel generator equipped with the venturi cyclone; (c) top view of the diverging section of the venturi section; (d) details of the converging elbow of the venturi section; (e) schematic diagram of the oil trap; and (f) belt skimmer of the oil trap.

To evaluate the pollutant removal efficiency of the venturi cyclone, a sampling tube system was utilised to measure the levels of pollutants at the outlet of the diesel generators before and after the installation of the venturi cyclone on the diesel generator. Four pollutants were able to be measured by using the sampling tube system, namely hydrocarbons (propane and butane), SO_2, NO_x, and CO_2. Additionally, the induced back pressure was measured by using a pressure gauge since the excessive back pressure can cause adverse effects on the efficiency of diesel generators. The removal efficiencies, defined as the difference between the concentrations of the pollutant before and after installation of the venturi cyclone divided by the concentration of the pollutant before the installation as expressed in Equation (1), applicable to different diesel generators at various loadings, are listed in Table 1.

$$\text{Removal Efficiency} = \frac{c_o - c_f}{c_o} \times 100\% , \quad (1)$$

where c_o and c_f are the concentrations of the pollutants at the outlet of the diesel generator before and after installation of the venturi cyclone on the diesel generator, respectively. It is found that the removal efficiency of hydrocarbons, NO_x, SO_2, and CO_2, regardless of the generator capacity and loading, vary from 40.0% to 98.7%, and the average removal efficiency of hydrocarbons, NO_x, SO_2, and CO_2 are 88.2%, 69.2%, 78.1%, and 84.7%, respectively. The high average removal efficiency shows that the venturi cyclone can effectively remove the pollutants as well as achieve decarbonisation to provide a sustainable, healthy, and clean environment for personnel on construction sites. Apart from that, the venturi cyclone can alleviate noise impact and thermal impact. Regarding the noise impact, the venturi cyclone incorporates noise mitigation features similar to that of a reflective muffler. Noise measurement was conducted by an acoustic testing consultant for a 100 kVA generator equipped with the venturi cyclone operating at 75% loading conditions. The Sound Power Level of the 100 kVA generator was reduced by 2.5 dB, from 99.5 dB to 97 dB showing that the sound power was reduced by 44%. In the case of thermal impact, the venturi cyclone employs water as the media for capturing pollutants in diesel exhaust. The gas exhaust is cooled by the water reservoir from 500°C to below 78°C, revealing a significant temperature reduction. The cooling effect lowers the fire and explosion risks, particularly in semi-enclosed workplaces such as underground spaces and tunnels. Besides, it reduces the localised thermal impact on construction workers resulting in adverse physiological effects such as heat stroke and heat exhaustion.

3. Dewatering bag system

There are lots of construction activities due to infrastructure development and urbanisation and a substantial amount of construction and muck waste, including excavated soil and construction sludge, is generated. The excavated soil is the soil produced by the excavation process in building foundations and tunnelling (Katsumi, 2015) whereas the construction sludge is the sludge or slurry generated by construction works such as cast-in-place concrete piles and shield tunnels (Kamon et al., 1993). The excavation deposition waste accounts for a large portion of the total construction and demolition waste. From recent statistics, the total amount of construction and demolition waste reaches over 740×10^6 tonnes where the excavated soil amounts to 598×106 tonnes, accounting for more than 80% of the total construction wastes in China (Guo et al., 2022). Specifically, construction sludge is accountable for more than 50% of the total construction waste in Shanghai and Shenzhen. Moreover, construction sludge is close to 95% of the total construction waste in Hangzhou. Hence, there is an urgent need to reduce the amount of construction and demolition waste to release the pressure on the landfill sites and save the work of sludge treatment. A dewatering bag system is one of the solutions to mitigate the problem.

The dewatering bag system consists of two dewatering bags made of geotextiles, a submersible water pump, and a 6 m-long roll-off dumpster slightly tilted to prevent water leakage onto the ground, as illustrated in Figure 2(a). Sludge or slurry generated from earthworks is pumped into the dewatering bags one by one. When both bags reach their

Table 1. Pollutant removal efficiency and back pressure of different diesel generators and loadings.

Generator capacity (kVA)	Loading of generator (%)	Removal efficiency (%)				Back pressure (kPa)	Allowable back pressure of generator (kPa)
		Hydrocarbon	NO_x	SO_2	CO_2		
100	25	73.9	82.0	64.7	78.6	1.5	20
	50	90.0	75.6	97.7	68.8	1.8	
	75	66.6	90.0	96.7	68.0	0.9	
200	25	85.5	45.5	53.7	98.7	1.4	
	50	94.3	40.0	87.1	98.0	1.8	
	75	92.8	55.0	80.6	97.1	2.7	
270	25	93.3	62.5	60.0	83.3	1.4	
	50	99.3	85.0	80.0	83.3	1.5	
	75	98.4	87.5	82.3	86.7	1.5	
Average		88.2	69.2	78.1	84.7	1.6	

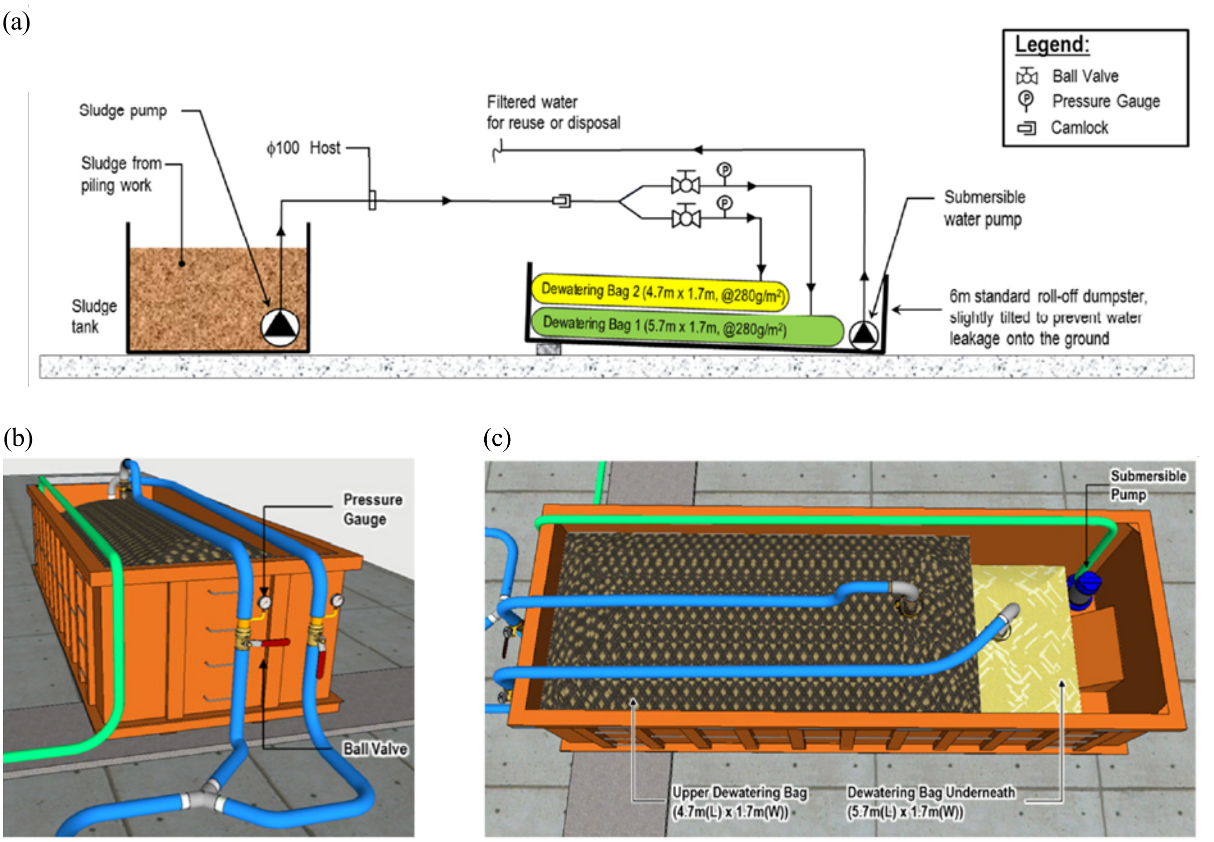


Figure 2. (a) Schematic of the dewatering bag system; (b) 3D diagram of the dewatering bag system;and (c) 3D diagram of the dewatering bag system.

maximum capacity, they are allowed to settle overnight to reduce the water content of the consolidated soil because water can be removed through the geotextile due to its porous layered structure. Apart from overnight settling, the consolidation processes can also be expedited by squeezing the bags to remove the embedded water mechanically using an excavator. Eventually, the geotextile bags are cut off and the relatively dry consolidated soil is poured into the dumpster. The consolidated soil is either disposed of in public fills or stored for subsequent construction usages.

3.1. Geotextile dewatering bag

Geotextiles are a group of geosynthetics, and different types of geotextiles are available to choose in order to suit various needs in geotechnical engineering (Sarsby, 2007). To select the appropriate type of geotextile based on the performance outcome, geotextiles with different fabric densities were characterised through trials. The geotextiles with the fabric densities of 280 g/m^2, 340 g/m^2, and 400 g/m^2 were considered in the investigation. The total suspended solids in the influent and effluent were measured with reference to the test method stipulated in APHA 17e 2540D "Total Suspended Solids Dried at 103-105°C" (American Public Health Association, 2022). First, a standard glass-fibre filter was weighed by using an analytical balance, and then the glass-fibre filter was inserted into filtration apparatus consisting of a Büchner funnel, a vacuum flask, and a vacuum pump. A well-mixed sample was placed in the Büchner funnel connected to the vacuum flask and the vacuum pump for filtration, and subsequently, the solid residue on the filter was dried at 103-105°C until the mass became constant. The mass difference of the filter before and after the filtration was regarded as the total suspended solids which can be expressed as:

$$\text{Total Suspended Solids} = \frac{w_t - w_f}{V}, \quad (2)$$

where w_t is the total mass of the filter including residue solids, w_f is the mass of the filter only, and V is the volume of the sample. The filtration efficiency is defined as the total suspended solids of the effluent divided by the total suspended solids of the influent. Additionally, the density and water content of the consolidated soil after dewatering were measured via a dewatering method where the sludge-filled dewatering bag was allowed to settle naturally overnight, and then the soil sample was extracted the following morning. The density of the consolidated soil was determined via a gravimetric method where the mass was measured using the analytical balance, and the volume was measured using a measuring cylinder partially filled with water. With regard to the water content, the test method in APHA 20e 2540G "Total, Fixed, and Volatile Solids in

Solid and Semisolid Samples" (American Public Health Association, 2022) was referenced, where the standard glass-fibre filter and filtration apparatus were employed to filter the sludge. The filtered solid residue was referred to as the wet sample. The filtered solid residue was dried at 103-105°C, and this was referred to as the dry sample. Next, the wet sample and the dry sample were weighed using the analytical balance. The water content can be determined by:

$$\text{Water Content} = \frac{w_w - w_d}{w_w} \times 100\% \,, \tag{3}$$

where w_w is the mass of the wet sample, and w_d is the mass of the dry sample.

3.2. Comparative study

Table 2 summarises the characteristics of geotextiles with different fabric densities. It is found that the total suspended solids of the influent ranges from 180,000 mg/L to 210,000 mg/L while those of the effluent are from 96 to 600 mg/L, showing the filtration efficiency of 99.67%, 99.95%, and 99.90% for geotextiles with the densities of 280 g/m^2, 340 g/m^2, and 400 g/m^2, respectively. The high filtration efficiency demonstrates that geotextiles with these three densities are good candidates for the dewatering bag. In terms of the consolidated soil in the dewatering bags, the densities of the consolidated soil after filtration through different geotextiles were similar, from 1.2 g/cm^3 to 1.4 g/cm^3, while the moisture contents of the consolidated soil of those ranged from 52% to 58%, illustrating the comparable results. In other words, the performances of the geotextiles, with respect to the filtration efficiency, the density and water content of the consolidated soil, with different fabric densities were close to each other while the prices of the geotextiles with the densities of 280 g/m^2, 340 g/m^2, and 400 g/m^2 were HK$19/m^2, HK$25/m^2, and HK$31/m^2, respectively. The geotextile with the density of 280 g/m^2 was shortlisted, due to the lowest price and comparable effectiveness, for further analysis.

Following the characterisation of the geotextiles, a comprehensive cost analysis was conducted. Conventionally, the sludge handled by a licensed collector for disposal is at a rate of approximately HK$1,600/truck carrying 4.5 m^3 of sludge, and the unit cost for handling the sludge by the licensed collector is HK$356/m^3. In the case of the dewatering bag system, the costs of the dewatering bag, dump truck, and disposal cost of consolidated soil are HK$900, HK$600, and HK$555, respectively, for 25 m^3 of the sludge equivalent to the volume of the dumpster. Hence, the unit cost of handling the sludge using the dewatering bag system is HK$83/m^3. Besides, it required 1.5 man-hours to operate the dewatering bag system. Apart from the cost, the use of the dewatering bag system to handle construction sludge yields other benefits. The consolidated soil can be utilised for other construction purposes such as site formation and reclamation pre-loading. Furthermore, the filtered water can be reused on sites for cleansing and wheel washing. Hence, the employment of the dewatering bag system can achieve resource reutilisation, economisation, and sustainability.

Table 2. Characteristics of the geotextiles with different fabric densities.

Fabric density (g/m^2)	Unit cost (HK$/m^2)	Total suspended solids (mg/L)		Filtration efficiency (%)	Consolidated soil in dewatering bag	
		Influent	Effluent		Density (g/m^2)	Moisture content (%)
280	19	180,000	600	99.67	1.4	56
380	25	200,000	96	99.95	1.3	52
400	31	210,000	210	99.90	1.2	58

4. Deodorising sewage tank

In construction sites, temporary flushing toilets are necessary sanitary facilities, and the substantial sewage generated by construction workforces on site is usually stored in a steel sewage tank for collection by service providers. However, the conventional sewage tank encounters several problems, namely hygiene concerns and a pungent smell, primitive operation design imposing health risks when collecting the sewage, missing water level indication, and tank capacity mismatch leading to operational inefficiencies. These problems render the conventional sewage tank cost-ineffective and inconvenient to use. To rectify these problems, a deodorising sewage tank has been developed for sewage storage where four distinctive features are incorporated: 1) Photocatalytic deodoriser, 2) built-in pipework and safety guardrails, 3) cathodic protection, and 4) optimised capacity and visual indication of the liquid level. Figure 3(a) shows the deodorising sewage tank. The special components of the deodorising sewage tank are presented in the following.

4.1. Photocatalytic deodoriser

For the deodoriser, a photocatalyst is used for deodorisation. Titanium oxide (TiO_2) is utilised as the photocatalyst to break down air pollutant molecules such as ammonia and hydrogen sulphide into carbon dioxide and water. The working principle of the TiO_2 is that photogenerated charge carriers are formed by TiO_2 by absorbing ultraviolet (UV) light corresponding to the band gap (Nakata and Fujishima, 2012). The photogenerated holes in the valence band diffuse to the TiO_2 surface and react with absorbed water molecules to form hydroxyl radicals (•OH). Next, the photogenerated holes and the hydroxyl radicals oxidise the air pollutant molecules on the TiO_2 surface, and meanwhile, electrons in the conduction band react with molecular oxygen in the air to produce superoxide radical anions (O_2•-). Hence, the final product in the oxidation and reduction is CO_2 and water. Figure 3(b) illustrates the design of the deodoriser incorporating the photocatalyst and UV lamp to activate the photocatalyst. The deodoriser mainly consists of three components, i.e., (i) ceramic honeycomb filter coated with the photocatalyst, (ii) four units of UV lamps with the power rating of 7 W and peak wavelength of 370 nm, and (iii) polypropylene (PP) hollow ball packing media sprayed with the photocatalyst. The ceramic honeycomb filter provides large surfaces coated with the TiO_2 photocatalyst to react with air pollutants, and the PP packing media at the downstream of the deodoriser serve to physically protect the light-emitting diode (LED) lamps and provide additional photocatalytic oxidation for gas purification. A performance test was conducted to evaluate the removal efficiency of the deodorisation using the concentration of ammonia as the basis of merit because urine contains certain amounts of ammonia where the concentration of NH^3-H in urine is 1,963 mg/L (Başakçilardan-Kabakci et al., 2007). The concentrations of the ammonia at the outlet of the deodorising sewage tank with and without the deodoriser were measured via the sampling tube system. It was found that the concentration of ammonia without the deodoriser was 0.15 ppm and that with the deodoriser was 0.005 ppm, demonstrating that the removal efficiency was as high as 97%. The deodoriser is effective in removing ammonia and odour and hence resolving the hygiene concerns arising from stored sewage.

4.2. Built-in pipework and safety guardrails

Conventionally, for each sewage collection, the collection operator is required to climb onto the top of the sewage tank several times manually carrying the suction pipe followed by connecting the suction pipe to the sewage tank for removal of the sewage, and then the collection operator needs to climb down from the sewage tank with the suction pipe, as depicted in Figure 3(c). Additionally, the ladders of the sewage tank raise concerns in regard to safety and ergonomic aspects. These repeated operations by way of the ladders impose a potential hazard in that the collection operator may fall from the sewage tank leading to injury or even fatality. To solve these problems, the pipework is built on the deodorising sewage tank to couple with the suction pipe via Camlock for fast connection so that the collection operator needs not climb onto the top of the deodorising sewage tank (Figure 3[d]). Besides, the deodorising sewage tank is also equipped with a self-developed "On-ground Push-up Guardrail System" which can eliminate the falling risk of the operator from the deodorising sewage tank. In the case of the conventional sewage tank, the required time for one collection of the sewage volume of 2 m^3 was 13 minutes while the required time for that of the deodorising sewage tank, whose volume is 8 m^3, was 13.5 minutes. Even though the volume of the deodorising sewage tank is four times that of a conventional sewage tank, the required time for the sewage collection is similar. The built-in pipework and safety guardrails are able to not only enhance the sewage collection efficiency but also improve the safety of the operator.

4.3. Cathodic protection

Sewage is composed of multiple pathogenic and non-pathogenic bacteria, organic and inorganic chemicals, and suspended and dissolved compounds (Khadom et al., 2015), resulting in considerable toxicity and contributing to corrosive environments (Srivastava et al., 2020). Corrosion is a significant threat to the service life of equipment as deterioration may lead to leakage, failure, and impact on the operators and the environment (Faisal et al., 2018). It is unlikely to implement simplistic anti-corrosion measures, such as painting, to the inner surfaces, so a cathodic protection system is used for the prevention of corrosion. Cathodic protection is a technique used for controlling the corrosion of a metal surface by making it the cathode of an electrochemical cell. A simple method of cathodic protection is to connect the metal to be protected to a more readily corroded "sacrificial metal", i.e., a metal at a higher ranking along the electrochemical series. It is found that an aluminium sacrificial anode of 1.6 kg is sufficient for sustaining corrosion protection of the deodorising sewage tank for one whole service year given that the dimensions of the deodorising sewage tank is 3 m × 2.3 m × 1.8 m (L×W×H). In other words, the corrosion processes of the deodorising sewage tank can be effectively halted by replacing the aluminium sacrificial anode with a new one on a yearly basis.

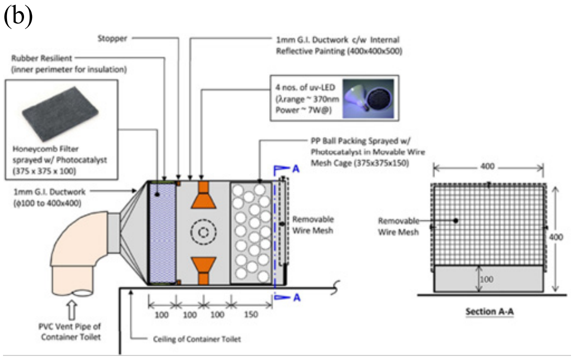
4.4. Optimised capacity and visual indication of the liquid level

The capacity of a conventional sewage tank is typically 6 m^3 to 8 m^3 while the maximum pumping volume of each sewage collection is 12 m^3, implying that the capacity of each sewage collection is not fully utilised. In view of such mismatch that leads to operational inefficiency, the design capacity of the deodorising sewage tank is optimised to about 13 m^3 attempting to achieve the maximum pumping volume to reduce the number of the sewage collection trips.

Another drawback of the conventional sewage tank is the lack of indication of the liquid level so it is difficult to assess the most appropriate time to arrange for sewage collection. In the common practice, the arrangement of sewage collection is determined based on site personnel's experience, which involves subjective judgement and may take place when the sewage tank is about 50% to 70% full. To promote the efficiency of the deodorising sewage tank, it is designed to install a liquid level indicator. However, traditional water level indicators are not applicable to the deodorising sewage tank, because electrical contact-type water sensors cannot be used for sewage and non-contact type sensors such as infrared or ultrasonic detectors are too delicate for the harsh and variable site environment. Thus, a new type of liquid level indicator was developed. The mechanism is simple and reliable, where the system consists of a vertical guide tube and polyethylene float, as illustrated in Figure 3(e). The indicator with a counterweight in the vertical tube slides up and down on the outside of the tube driven by the polyethylene float, tallying with the liquid level due to the buoyancy force.

(a)

(b)



(c)

(d)

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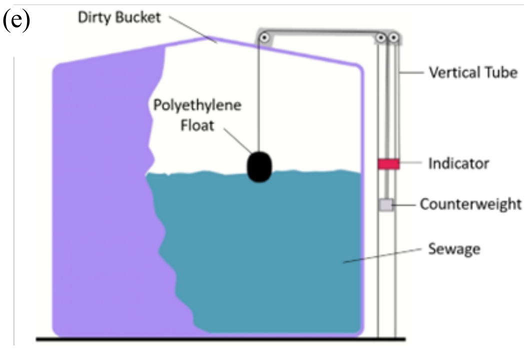

Figure 3. (a) The deodorising sewage tank; (b) schematic of the deodoriser; (c) collection operator collecting sewage from the top of a conventional sewage tank; (d) collection operator collecting sewage from the deodorising sewage tank via Camlock fast connection; and (e) schematic of the liquid level indicator.

Lastly, a cost-benefit analysis of the deodorising sewage tank has been conducted where the deodorising sewage tank had been employed in a 35-month construction project with a maximum workforce of 500. Table 3 summarises the cost and benefit details of the conventional sewage tank and the deodorising sewage tank. The numbers of sewage collection trips for the sewage tank and deodorising sewage tank during the project were 1,085 and 497, respectively. The saving of the latter was owing to the larger volume and liquid level indicator of the deodorising sewage tank. The cost of the sewage collection was HK$550/trip by a licenced collector; thus, the cost for the sewage collection of the conventional sewage tank and deodorising sewage tank were HK$596,570 and

HK$73,350, respectively, showing a substantial saving of 54% for the latter. The costs of fabricating the sewage tank and deodorising sewage tank were HK$29,500 and HK$72,000. Consequentially, the total cost of the sewage tank and deodorising sewage tank were HK$626,250 and HK$345,350, revealing a cost saving of HK$280,900 by using one deodorising sewage tank for the project. Apart from this considerable cost reduction, more importantly, the employment of the deodorising sewage tank reduces the hazards of personnel falling from the sewage tank, improves the efficiency of the sewage collection, and mitigates the deleterious smell so as to improve construction environments.

Table 3. Comparison of the cost and benefit details of the conventional sewage tank and the deodorising sewage tank.

Item	Conventional sewage tank	Deodorising sewage tank
Volume (m^3)	8	13
Number of sewage collection trips	1,085	497
Unit rate of sewage collection	HK$550/trip	
Cost of sewage collection	HK$596,750	HK$273,350
Fabrication cost of tank	HK$29,500	HK$72,000
Total cost	HK$626,250	HK$345,350
Cost saving	HK$280,900/deodorising sewage tank	

5. Conclusion

This paper showcases several self-developed, innovative, and practical environmental technologies to improve the sustainability in the construction industry. The technologies include the venturi cyclone, dewatering bag system, and deodorising sewage tank. The venturi cyclone is the accessory for diesel generators to remove the generated air pollutants such as hydrocarbons, NO_x, SO_2, and CO_2. The results show that the average removal efficiency of the venturi cyclone ranges from 69.2% to 88.2% depending on the types of air pollutants, and the average back pressure of the venturi cyclone is 1.6 kPa, which is negligibly small. With regard to the dewatering bag system, it makes use of geotextiles to remove the water in construction sludge or slurry in order to reduce the volume for sludge handling and possible reutilisation. The filtration efficiency of geotextiles can reach 99%, and the cost of using the dewatering bag system in lieu of the traditional way of handling by licensed collectors can be reduced by three-fold. In the case of the deodorising sewage tank, it consists of four features, i.e., photocatalytic deodoriser, built-in pipework and safety guardrails, cathodic protection, and optimised capacity and visual indication of the liquid level, to improve the construction site environment and enhance the sewage collection efficiency. With reference to a real construction project, 46% of the total sewage collection cost can be saved using the deodorising sewage tank compared to a conventional sewage tank. It is advocated to develop and employ more new technologies for use in the construction industry to achieve decarbonisation and improve sustainability.

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Mr Tze Keung Ken Ho is Senior Manager (Sustainability and Environment) of Hip Hing. He is responsible for leading the corporate towards Net Carbon Zero and governing green building standards in construction projects. He integrates innovations and technologies in construction process to reduce carbon emission, which include venturi cyclone, dewatering bag system and deodorising sewage tank. Besides, together with other industrial partners, he promotes electrification in construction sites to reduce consumption of fossil fuel and so as to reduce carbon emission.

Mr Wai Yip Ken Leung graduated from Hong Kong Polytechnic with BEng (Hons) in Building Services Engineering in 1992 and The University of Hong Kong with MSc in Environmental Management in 1997. He had worked as an Environmental Consultant in Hong Kong Productivity Council for 6 years to provide professional solutions to the industry. He joined Hip Hing in 2000. With strong ability of problem solving, he has led a team of environmental engineers and developed a series of innovative inventions to tackle many environmental issues, such as venturi cyclone, dewatering bag system and deodorising sewage tank, to improve the environment for the people working in construction sites. These mentioned environmental innovations were patented successfully in Mainland China and Hong Kong.

Ir Kwok Ho Mok joined Hip Hing in 1982 and has been an Executive Director since 2011. He graduated from Hong Kong Baptist College in 1982 with a Diploma in Civil Engineering. He subsequently obtained a Master of Science in Interdisciplinary Design and Management from The University of Hong Kong in 2007. He is a Fellow member of both HKICM and HKIE in the Civil and Building Disciplines, and past Chairman of the HKIE Building Division. He also obtained the accreditation of CIC BIM Manager. He has over 40 years of experience, with particular expertise in reinforced concrete, pre-stressed concrete, structural steel and precast structures and a variety of foundation types. Additionally, he promotes innovations and technologies for use in the construction industry to enhance the safety, quality and productivity for the construction projects. Specifically, he is experienced in the innovations such as Building Information Modelling (BIM), Design for Manufacture and Assembly (DfMA) and Modular Integrated Construction (MiC).

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