An assessment of heavy metal contamination in the marine soil/sediment of Coles Bay Area, Svalbard, and Greater Bay Area, China: a baseline survey from a rapidly developing bay

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Abstract

The objective of this research is to investigate the pollution levels of tin (Sn), arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), and zinc (Zn) of soil/sediment taken in Coles Bay Area (CBA), Svalbard, and Great Bay Area (GBA), China, in an attempt to evaluate the pollution potential related to recent development in the areas. A total of 150 soil/sediment samples were collected in each location. Heavy metal concentrations were detectable levels at all sites and the values of Cd of all soil/sediment samples were higher than Dutch Target and Intervention Values. Heavy metal concentration in soil/sediment was further analyzed by principal component analysis (PCA). It was revealed that three components were found in two studying sites and contributed 60.2% and 75.9% of variations to reflect soil/sediment quality in CBA and GBA, respectively. Based on the results of KMO (0.52) and Bartlett's test ($p < 0.000$), there are 32.1%, 15.6%, and 11.1% and 39.45%, 19.01%, and 17.52% of the variance in the first, second, and third component explained that the metal concentration of Pb, Cd, and Sn was highly correlated with the soil/sediment quality in CBA and GBA, respectively. Among these three heavy metals, Cd concentration was the common dominant factor to affect soil/sediment quality in these two study sites. It is recommended that investigation of the sources of pollution (either point or non-point source) during CBA or GBA development and management together with consideration of abiotic (soil)-biotic (organisms) interactions should be taken into account when choosing suitable remediation strategies in the future.

Keywords Heavy metals · Principal component analysis (PCA) · Dutch Target and Intervention Values · Great Bay Area (GBA) · Coles Bay Area (CBA) · Svalbard

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Introduction

Estuaries are important nursery area for a juvenile marine organism such as crustaceans and fishes with less susceptible to predation (Sogard 1992; Potter et al. 2014) and provided main feeding areas for diadromous species due to steadily physio-chemical and osmoregulatory properties of estuaries area regulated by aquatic plants such as macrophytes. However, estuaries areas were heavily polluted by human activities such as land exploitation and reclamation, frequent agricultural activities, and tourism development recently. Thus, a large amount of inorganic toxic pollutants such as heavy metals are released from anthropogenic inputs (Ong 1995). Recently, due to increased population and industrial activities, coastal areas received industrial effluents such as heavy metal wastewater, petrol products in the smelting industry, and domestic sewage. As the heavy metals from toxic waste are binded to organic molecules and thus accumulating in both abiotic and biotic components naturally such as solid

form (soil erosion, the remains of pesticides, and fertilizers), liquid form (leachates from surface runoff, water drainage), and gas form (waste gas deposition particulate matter emitted as ash and smog). The particles are thus depositing in coastal sediments (Storelli et al. 2001). Therefore, the surface sediment of estuaries areas could become heavily polluted with heavy metals.

The fluctuation of sediment properties in estuary areas and reactive heavy metals is present in water bodies and organisms (Zulkifli et al. 2010) due to the disturbance of chemical equilibrium of natural form of heavy metal by various pollutants and it was ready to bioaccumulate in organisms. Such bioavailable form of heavy metals concentration was transferred along with the food web and food chain in an ecosystem (Harikumar and Nasir 2010; Joksimovic et al. 2011). In order to conserve valuable natural resources of estuaries areas, evaluation of heavy metal in the areas is essential. The data can reflect sediment quality such as pollution states and degradation level nutrient cycle and understand the current states of actual/chronic effect on water pollution because it was well known that sediment can be regarded as important indicators for the sites (Atta and Xiao 2019; Allafta and Opp 2020; Kadhum 2020). Recent findings revealed that severe pollution was found in estuaries areas such as Nigeria (Tunde and Oluwagbenga 2020), Malaysia (Udechukwu et al. 2015), Brazil (Fonseca et al. 2020), New Zealand (Bastakoti et al. 2018), Atlantic Ocean (Bessa et al. 2020), Patagonia (Idaszkin et al. 2020), Egypt (Youssef et al. 2020), Italy (Arienzo et al. 2020), Bangladesh (Hossain 2019), and South Africa (Babatunde et al. 2015). Chen et al. (2010) found that an elevated concentration of Fe, Mn, and Zn was found in Daya Bay, China, probably due to improper treatment of industrial effluent. On the other hand, van den Heuvel-Greve et al. (2016) detected organotin was present in sediment and suggested to continue monitoring contaminated levels in Coles Bay, Svalbard. Generally speaking, the degraded estuaries have common characteristics: deteriorated coastal vegetation, hardened shoreline, and sediment/turbidity influx (Kennish 2012). Therefore, intense human activity such as land exploitation and tourism activities further reducing ecosystem goods and services. As both fauna and flora, biodiversity and complexity depend not only on the physical status of sediment such as temperature and salinity of water but also pollution level generally found in the estuary region. The sustainability of estuary habitat (i.e., freshwater with low salinity from river flow into marine habitat with high salinity) facilitates a huge amount of food availability to organisms such as the decay of plants and animals, organic debris, and dissolved particulate organic matters. Investigation of sediment quality can thus reflecting pollution status be disturbed by anthropogenic activities and it also acts as a basis to understand an indicator of water pollution in the estuary. However, there is scarce information on heavy metal pollution in newly developing areas in the year of 2019 such as Greater Bay Area (GBA)

and Cole Bay Area (CBA). Henceforth, this study evaluates the heavy metal status of soil/sediment in CBA and GBA in an attempt to provide baseline information on soil management, namely to prescribe ameliorative measures in the form of physical manipulation.

## Materials and methods

Site description

Cole Bay Area (Svalbard) was located in Svalbard where a location is a Norwegian group of islands in the Arctic Ocean north of continental Norway, about 650 mi (1050 km) from the North Pole (Fig. 1). It is the northernmost year-round settlement with a population of 2379 in the year 2019.

Greater Bay Area (China), including Dongguan (area: 2460 km^2; population: 8,392,200), Foshan (area: 3798 km^2; population: 7,906,000), Guangzhou (area: 7434 km^2; population: 14,904,000), Hong Kong (area: 1107 km^2; population: 7,486,400), Huizhou (area: 11,347 km^2; population: 4830000), Jiangmen (area: 9507 km^2; population: 4,598,200), Macao (area: 33 km^2; population: 667,400), Shenzhen (area: 1997 km^2; population:13,027,000), Zhaoqing (area: 14891 km^2; population: 4,151,700), Zhongshan (area: 1784 km^2; population: 3,310,000), Zhuhai (area: 1736 km^2; population: 1,891,000), is an integration of agricultural, commercial, and industrial activities for newly develop economic zone in the region of the Pearl River Delta (Fig. 2).

Sample collection and chemical analysis

A total of 150 surface soil/sediment samples were collected in 2019 from two sites: Cole Bay Area and Greater Bay Area, and the sample locations were shown in Figs. 1 and 2. In order to understand the accumulation of heavy metal pollutants in sediment nearby coastal areas, samples were taken in the downstream of the river, and locations were recorded by using GPS (Table 1). Sampling was conducted according to the USEPA method (EPA 600, Mason 1992). All the samples were kept in an iced box transported to the laboratory and stored at – 20 °C until further analysis.

Soil/sediment was homogenized and dried in the freeze drier for 10 days. Total metals in sediment samples including As (metalloid), Cd, Cr, Hg, Pb, Sn, and Zn were extracted by HCl-HNO3-HF microwave digestion USEPA Standard Method 3051A (USEPA 2007a) and 3050B (USEPA 2007b). Standard reference material National Institute for Standards and Technology (NIST) 2711 Montana soil was used to verify the accuracy of metal determination, and the recovery percentage was 99.2 %, 99.5%, 98.2%, 99.5%, 98.5%, 92.5%, and 98.5% respectively. All of the digests were filtered through a 5C filter article and stored at 4 °C. As, Cd, Cr, Pb, Sn, and Zn in extracts
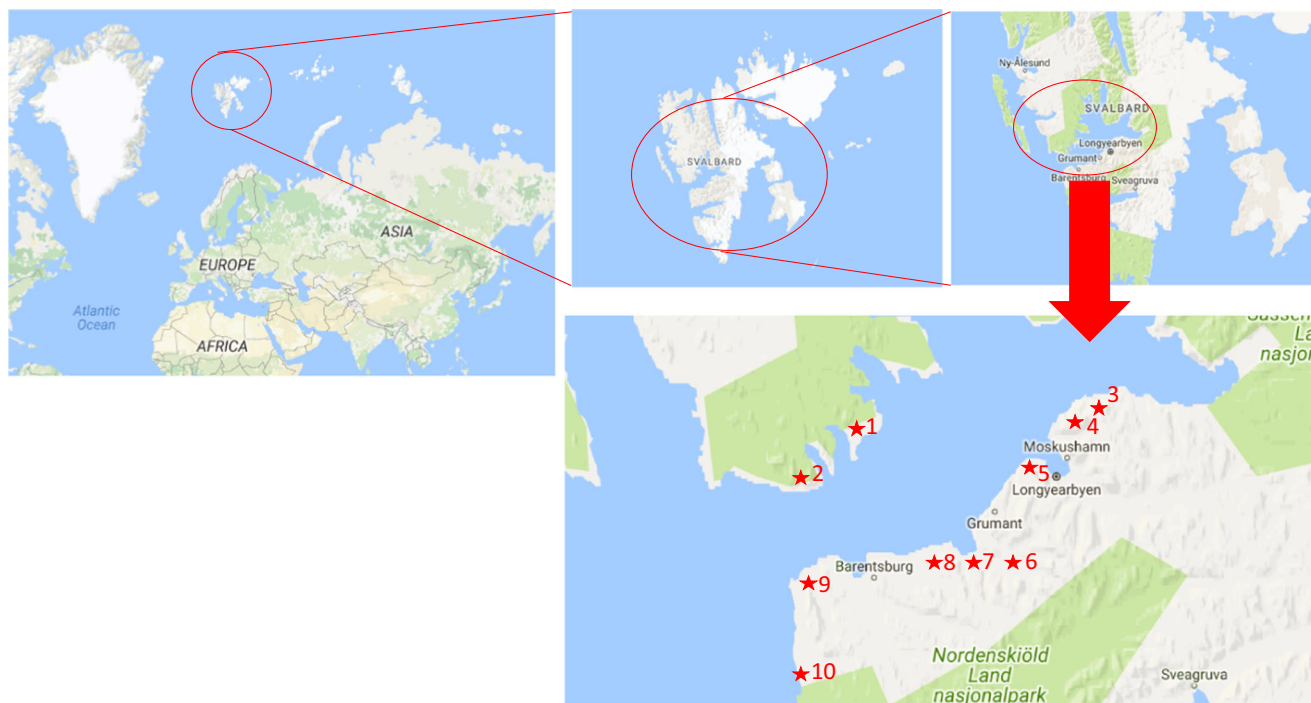
Fig. 1 Sampling locations in CBA, Svalbard

were determined by inductively coupled plasma optical emission spectrometry (Optima 3000 DV; Perkin Elmer) (USEPA 6010) (USEPA 2007c). A flow injection (Hg) system (FIAS-400 Flow injection Mercury/Hydride System; Perkin Elmer) was used to measure total Hg in samples. Metal contents were expressed as milligram per kilogram.

Principal component analysis (PCA) and statistical analysis

Variable input for the PCA included heavy metal concentrations in soil/sediment samples. The data were assessed by Kaiser-Meyer-Olkin (KMO) statistics (value is > 0.5), Bartlett's test (value is < 0.05), eigenvalue (value is > 1.0). Varimax—rotated—was applied to minimize the variations among the variables for each factor. All data were subjected to one-way ANOVA Duncan's multiple range test and T-test (< 0.05) using SPSS 16.0 software for further analysis. Means and standard derivation were calculated based on four replicates. Means were compared by Duncan's multiple range test.

Results and discussion

General characteristics of heavy metal contamination in CBA and GBA

A summary of heavy metal of soil/sediment measured at each sampling location given in Tables 1 and 2. The range of total

Sn, As, Cd, Cu, Pb, Hg, and Zn (in mg/kg) in sediment samples taken in CBA and GBA were 1.41–3.01, 1.74–6.99, 1.19–3.50, 1.63–9.40, 16.3–188.4, 1.17–5.26, and 0.06–4.83 and 1.41–46.88, 1.74–34.0, 1.19–9.23, 14.1–382, 23.3–538, 0.005–0.312, and 2.63–161, respectively. All soil/sediment in two sites exhibited Cd contamination levels were higher than Dutch value (i.e., 0.8 mg/kg) (VROM 2016). The current results revealed significantly higher Cd concentration found in all samples than the Cd concentration in the natural environment. Normally, heavy metals are present in the soil/sediment except it becomes contaminants in the environment. Due to human activities, heavy metal deposition in soil/sediment after refining and smelting is faster than the rate of metal generation by natural processes such as erosion and sedimentation (Wuana and Okieimen 2011, b); the possible pollutants include atmospheric deposition, smelting by-product, and inorganic minerals; and the losses by leaching and volatilization from tailings are thus accumulated in the bay areas. The mobile form of metal binded to the surface of natural materials and exposed directly to an environment and rendered in the habitat.

Interestingly, it was found that the variation of soil/sediment structure and a different topography in two sites leads to varying heavy metal concentrations in soil/sediment. In CBA, the major component of soil/sediment is cold desert soil formed from quick temperature fluctuation and weathering. On the other hand, in GBA, fertile soil/sediment was deteriorated by heavy urban activities resulting in erosion and soil/sediment compaction. Consequently, the loss of
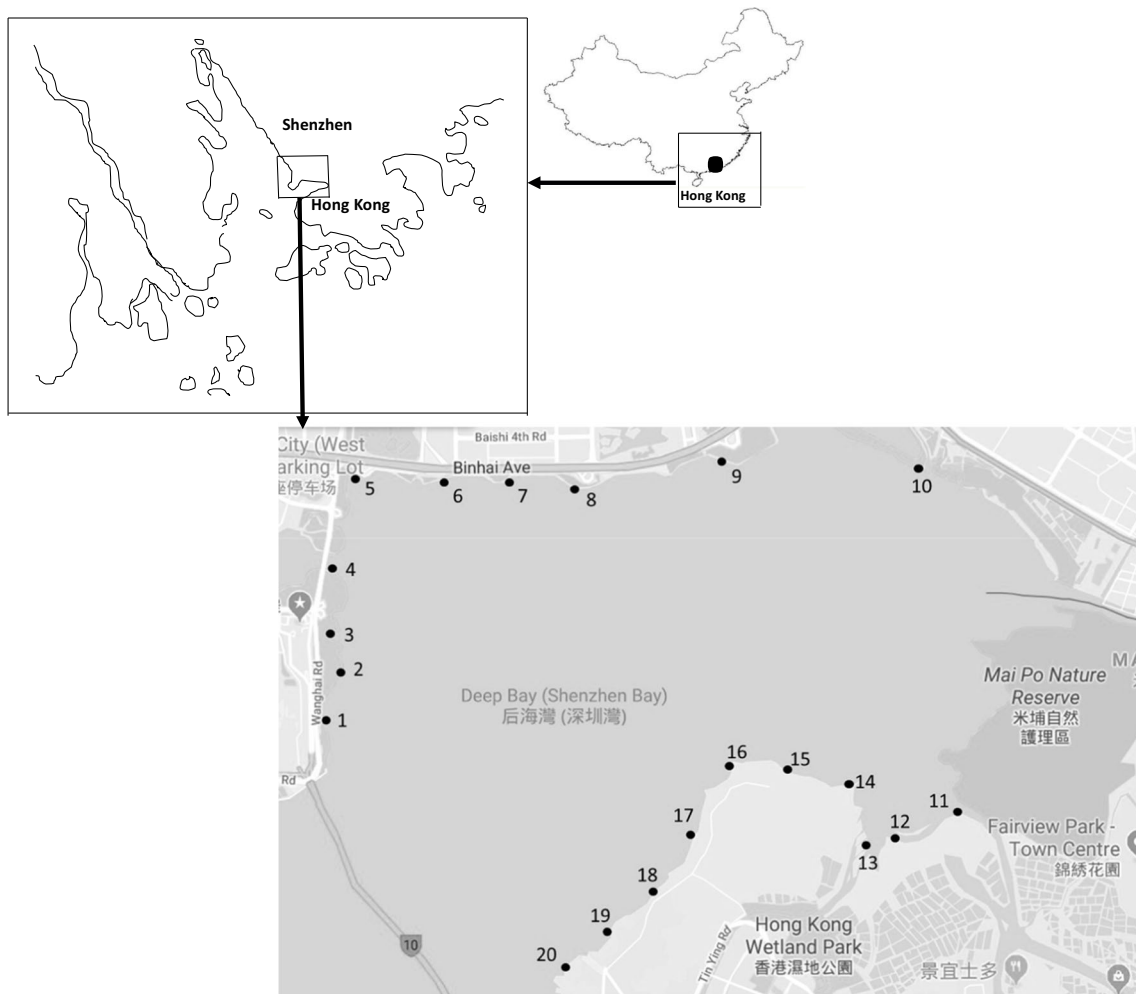
Fig. 2 Sampling locations in GBA, China

colloidal particles of soil organic matter in the sediment leads to the imbalance between sorption and leaching of soil/sediment lead to altering the available adsorptive surfaces

to bind heavy metals (Thonon 2006). Hence, there were varied metal contaminations in the soil/sediment between distinctly different locations.

Table 1 Heavy metal concentration of soil/sediment in CBA ($n = 5$, total 50 samples). Highlighted values indicated the concentration exceeds Dutch target and intervention values

Location	GPS reading		Heavy metal concentration (mg/kg, dry weight)*						
	GPS (North)	GPS (East)	Sn	As	Cd	Cu	Pb	Hg	Zn
1	78.284623	14.048613	3.36±0.28a	3.32±0.21ab	1.82±0.14b	3.66±0.41b	26.9±12.3e	2.81±0.22b	1.80±0.26a
2	78.210779	13.762969	3.17±0.94a	2.92±0.89b	1.74±0.35b	3.39±1.06b	36.3±11.3d	2.55±0.51b	1.82±0.28a
3	78.242162	15.471343	2.92±0.24a	4.52±0.29ab	2.87±0.23a	6.85±0.78a	54.7±25.1c	4.33±0.34a	2.25±0.33a
4	78.233204	15.383452	2.75±0.82ab	3.97±1.21ab	2.75±0.56a	6.33±1.99a	73.7±23.0b	3.93±0.79b	2.29±0.35a
5	78.239923	15.460356	1.58±0.13ab	5.43±0.35a	2.50±0.20a	6.71±0.76a	63.7±25.6bc	3.76±0.30b	2.44±0.36a
6	78.120655	15.103301	1.49±0.44ab	4.77±1.45a	2.39±0.48a	6.21±1.95a	131.3±26.9a	3.41±0.69b	2.41±0.32a
7	78.088952	14.971465	0.17±3.86d	5.59±0.36a	3.03±0.24a	8.12±0.92a	56.2±14.8c	3.27±0.26b	2.11±0.31a
8	78.093486	14.823149	0.81±5.92c	4.91±1.49a	2.90±0.59a	7.51±2.36a	169.7±16.3a	2.97±0.60b	2.12±0.33a
9	78.088952	13.916777	0.08±0.007e	5.42±0.35a	2.51±0.20a	6.01±0.68a	71.6±3.86b	1.47±0.12c	1.94±0.30a
10	78.050343	13.680571	0.08±0.024e	4.77±1.45a	2.40±0.49a	5.56±1.74a	81.4±5.92b	1.33±0.27c	1.96±0.29a
Dutch Target and Intervention Values, 2000 (the New Dutch List) (VROM, 2016)			19.0	29.0	0.80	36.0	85.0	0.30	140.0

*Within each location, means with the same letter are not significantly different according to Duncan's multiple range test at 5% level. The bolded data indicated the concentration was higher than Dutch Target and Intervention Values (VROM 2016)

Table 2 Heavy metal concentration of soil/sediment in GBA (*n* = 5, total 100 samples). Highlighted values indicated the concentration exceeds Dutch target and intervention values

Location	GPS reading		Heavy metal concentration (mg/kg, dry weight)*						
	GPS (North)	GPS (East)	Sn	As	Cd	Cu	Pb	Hg	Zn
1	22.493577	113.952181	1.78±0.03c	8.23±0.04b	3.61±0.08c	123±0.15b	59.2±1.86c	0.034±0.05c	30.4±1.22d
2	22.492288	113.954239	1.83±0.09c	34.0±0.02a	1.89±0.04d	327±0.12a	163.7±1.73b	0.044±0.07c	34.0±1.66d
3	22.504838	113.953393	1.41±0.06c	3.64±1.05d	1.71±0.17d	382±0.15a	164.3±2.11b	0.015±0.04c	32.7±1.88d
4	22.509121	113.953034	5.01±0.04b	3.06±0.14d	1.63±0.39d	21.8±0.61de	381.3±1.80a	0.016±0.08c	38.1±2.85d
5	22.511341	113.952690	8.88±0.03b	3.32±0.18d	1.99±0.15d	52.9±0.71d	215.7±3.60ab	0.022±0.02c	119.2±0.45b
6	22.519415	113.959311	3.82±0.43bc	9.79±0.03a	1.94±0.14d	68.2±0.31c	417.1±4.60a	0.059±0.09c	106.1±0.93b
7	22.519941	113.987124	1.53±0.02c	5.59±0.26b	3.99±0.08c	20.6±0.28de	44.6±1.65cd	0.117±0.03b	99.4±0.13b
8	22.520368	113.999486	1.91±0.09c	11.7±0.06a	1.19±0.16d	42.4±0.13d	23.3±2.91d	0.005±0.02c	48.3±1.95d
9	22.524015	114.009960	1.83±0.01c	6.81±0.07b	2.11±0.10b	34.5±0.14d	24.7±1.25d	0.007±0.01c	27.6±2.36d
10	22.519731	114.019574	2.25±0.08c	6.43±0.05b	1.62±0.10d	45.9±0.17d	47.1±1.43c	0.139±0.07b	25.8±1.38d
11	22.483569	114.024714	2.12±0.24c	6.76±0.02b	1.66±0.05d	65.0±0.36c	142±6.30b	0.257±0.04ab	161±0.52a
12	22.481350	114.019564	15.1±0.39b	5.78±0.09b	1.63±0.16b	63.1±0.53c	175±3.66b	0.176±0.02b	69.6±0.96c
13	22.479924	114.014243	5.27±0.08bc	4.16±0.04bc	9.23±0.26a	41.8±0.51d	106±1.37bc	0.166±0.04b	115±0.23a
14	22.480744	114.012356	2.14±0.04c	1.74±0.13d	1.89±0.13b	70.7±0.55c	175±3.67b	0.312±0.07a	55.9±0.86d
15	22.488807	114.003774	1.95±0.02b	2.51±0.12c	4.27±0.07b	29.7±0.22de	101±2.80bc	0.158±0.06b	57.6±0.33d
16	22.486429	113.995191	1.61±0.07b	3.18±0.14d	4.11±0.24b	14.1±0.45f	538±4.50a	0.027±0.09c	3.31±1.75a
17	22.486429	113.993991	11.14±0.57	4.16±0.15d	5.78±0.13b	36.8±0.50c	424±8.65a	0.122±0.04b	3.06±1.47a
18	22.474533	113.998669	46.88±0.08a	4.16±0.04bc	1.86±0.10b	35.5±0.17e	172±3.03b	0.135±0.09b	2.63±0.06b
19	22.469288	113.982146	12.35±0.81b	1.74±0.13d	2.85±0.07d	43.1±0.16d	67.7±1.05c	0.156±0.03b	49.0±0.318d
20	22.458195	113.975796	34.58±0.92a	7.13±0.06b	4.82±0.04b	26.1±0.05e	84.1±2.45bc	0.128±0.05b	155±0.874a
Dutch Target and Intervention Values, 2000 (the New Dutch List) (VROM, 2016)			19.0	29.0	0.80	36.0	85.0	0.30	140.0

*Within each location, means with the same letter are not significantly different according to Duncan's multiple range test at 5% level. The bolded data indicated the concentration was higher than Dutch Target and Intervention Values (VROM 2016)

Further analysis was conducted by PCA. The PCA is performed at each site on the heavy metal content of soil/sediment. The percent of variance (heavy metal concentrations) by all studying sites is presented in Figs. 3 and 4. The result exhibited the soil/sediment with similar properties was closer to each other and vice versa. It was revealed that three components were found in two studying sites and contributed 60.2% and 75.9% of variations to reflect soil/sediment quality in CBA and GBA, respectively. Based on the results of KMO (0.52) and Bartlett's test (*p* < 0.000), there are 32.1%, 15.6%,

and 11.1% and 39.45%, 19.01%, and 17.52% of the variance in the first, second, and third component explained the metal concentration of Pb, Cd, and Sn were highly correlated with the soil/sediment quality in CBA and GBA, respectively (Tables 3 and 4).

By comparing the concentration of pollutants of sediment in CBA and GBA, the source of pollutants may be attributed to the various industrial activities in CBA and GBA. According to the study of Najamuddin et al. (2016), the possible explanation was among different forms of heavy metal in

Table 3 Rotated component matrix for soil/sediment samples taken in CBA

Component	Eigenvalues		
	1	2	3
Sn	− 0.152	− 0.189	− 0.637
As	− 0.339	− 0.238	− 0.169
Cd	0.435	0.162	0.747
Cu	− 0.433	− 0.891	− 0.167
Pb	0.162	0.211	− 0.418
Hg	− 0.144	− 0.016	− 0.294
Zn	0.784	− 0.566	− 0.128
Eigenvalue	1.73	1.38	1.61
Contribution	32.1	15.6	11.1

Table 4 Rotated component matrix for soil/sediment samples taken in GBA

Component	Eigenvalues		
	1	2	3
Sn	− 0.123	− 0.213	− 0.181
As	− 0.124	− 0.145	− 0.185
Cd	0.154	0.114	0.125
Cu	− 0.133	− 0.111	− 0.014
Pb	− 0.107	0.087	− 0.109
Hg	− 0.158	− 0.185	− 0.200
Zn	− 0.441	− 0.256	− 0.282
Eigenvalue	1.08	1.25	1.90
Contribution	39.45	19.01	17.52

Fig. 3 PCA analysis of soil/sediment samples taken in CBA ($n = 5$, 50 samples in total) (index: V = sample sites)
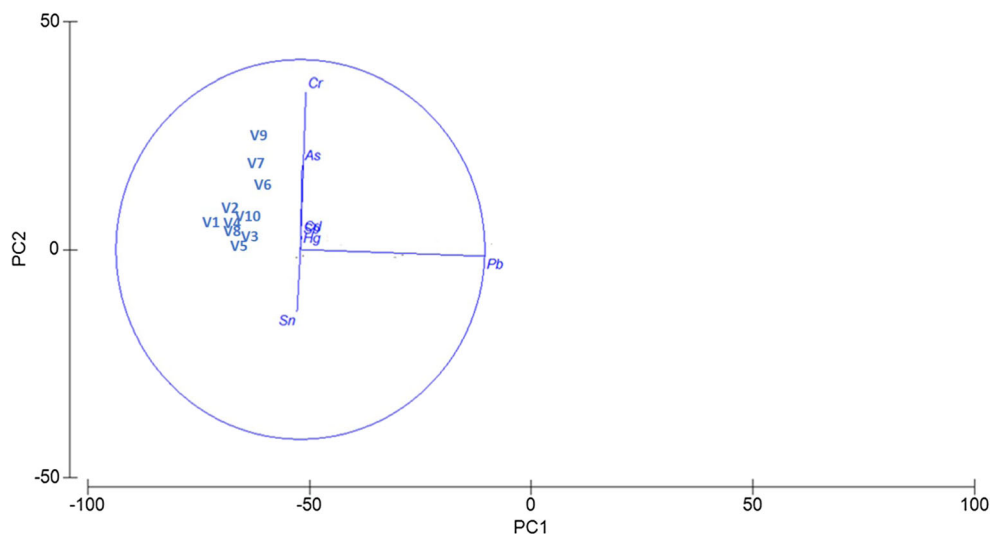

sediment such as carbonated reducible, oxidizable, exchangeable, and residual; exchangeable forms of metal can be acquired by marine organisms with the integration of suitable physical environment found in GBA such as turbidity, salinity, acidity, and alkalinity. The oxidizable, reducible, and carbonate forms of heavy metal transformed readily into exchangeable forms (Ma et al. 2016). Additionally, due to the intensive agricultural activities, a large amount of water or effluent with high organic matter component was discharged into the estuary and heavy metal binded to these organic matters gradually. As the organometallic compounds are biopersistent in nature henceforth once assimilated by an organism, it remains persistence for many years (Wuana and Okieimen 2011, b). As a result, heavy metals may bind to an active site of alkaline phosphatase commonly present in biotic and thus metabolism is disrupted (McGrath 1999). In addition, the function of mitochondria interfered in the basophilic cells of the hepatopancreas due to heavy metal reacts with

membranes, and this may be the biochemical basis for toxic effects on mitochondria (Vallee and Ulmer 1972)

Relationship between heavy metal contamination in soil/sediment and unique weather condition in CBA

There are two out of ten locations that exceed the guideline for Cd, Pb, and Hg concentration in CBA where the sampling locations are close to shipyards and coal-fire electric power stations in sites 6 and 8. Transport emission and increased electric consumption by visitors contributed unusual chemical composition of the sediment. Cd in soil/sediment may be comprised from the geological parent material and extraneous sources such as the long-distance transport of Cd by air current (Weinbruch et al. 2012), atmospheric deposition, and water from melting snow and glaciers due to global warming are the possible sources of metal deposited in soil/sediment (Samecka-Cymerman et al. 2011; Ruman et al. 2012;

Fig. 4 PCA analysis of soil/sediment samples taken in GBA ($n = 5$, 100 samples in total) (index: V = sample sites)
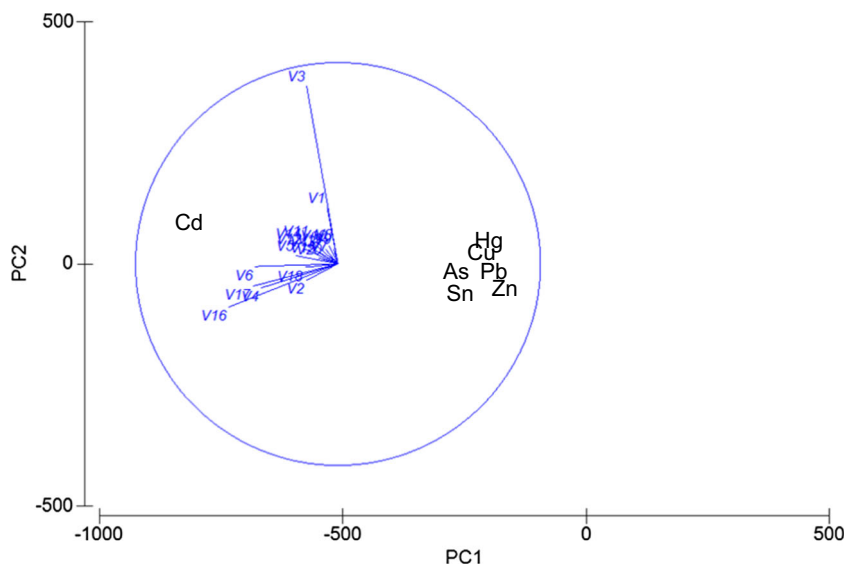
Weinbruch et al. 2012). The elevated Cd concentration found in soil/sediment may be subjected to large scale of such heavy metal emitted from the pollutant sources. On the other hand, the coal residue from the coal-fire power station and fly ash and particulate matter emitted from the chimney contained a high percentage of organic matter (as the original source of coal is plant residue) and could aid to bind heavy metal on sediment/soil. An extreme temperature changed during day and night in CBA leads to form aerosol, dust, fog, haze, fume, smog, smoke, soot, and particulate matter readily, and the findings were in line with Agrawal and Pottsmith (2000). Such toxicants were distributed pervasively and caused human health hazards including acute and chronic metal toxicity.

Furthermore, materials generated from coal-fired electric power stations included solid (coal residue), liquid (warm water), and gas (flue gas) and lead to land pollution (improper treatment of tailings, coal ash, overburden, and waste rocks), thermal pollution (degradation of water quality that change in an ambient temperature), and air pollution (such as nitrogen dioxide, sulfur dioxide, ammonium compounds which are dissolved in suspended water vapor to create acidic smog), and such pollutants further deposited into soil/sediment, producer and consumer in the tropical level of an ecosystem. Therefore, respective pollutants were accumulated into abiotic and biotic components in the natural environment and deteriorated environmental quality in CBA.

The impact of unlimited urban development on sediment/soil quality in GBA

The GBA region is under an ever-increasing anthropogenic impact, including local industrial center, reclamation, and alteration of coastal line and hence change of flowing water and sedimentary material in Pearl River Delta (PRD). Especially, four out of seven contaminants exceeded the guideline where the pollution sources are probably from illegal wastewater discharged from textile factories in sites 2 and 14. As the GBA is nearby the Pearl River Delta (well-known industrial area reported by Wan et al. (2020); Lu et al. (2020); Zhang et al. (2017)), the riverine system is suffering from various pollution by intense human activities. Heavy metals are thus depositing in sediment and cause enrichment. Recently, GBA experienced a reclamation project ti cope with economic growth and industrialization planned by the government after the COVID-19 pandemic. Anthropogenic activities resulting from the rapid development of commercial areas, industrial zone, coal-generation plants, transport, coal-fired power station, transportation pub, livestock, and agricultural activities make the main source contaminants in GBA. The soil/sediment in the seabed of the reclaimed land becomes anoxic and converted into oxidized conditions. Thus, the stable organic bound-heavy metal released into the water and entered into the sediment (Chen and Jiao 2008). The

anthropogenic impact leads to the degradation of marine ecology as well as food chains, contributing to a rapid transport of toxicants to final consumers through bioaccumulation and biomagnification.

Conclusion

The results from the current study revealed that sediment in CBA and GBA was heavily contaminated with heavy metals such as Cd/Pb/Sn according to PCA results. A significantly higher concentration of these heavy metals was found in sediments due to various anthropogenic activities in different locations. Besides, the availability of toxic metals appears to be elevated in the studying sites as the nature of the soil compositions altered substantially by natural and human activities, thus posing short- and long-term impacts to an ecosystem. Implementation of various strategies to mitigate heavy metal contamination is necessary to restore the bay areas such as frequent monitoring the anthropogenic activities especially in mining and smelting activities, microbial remediation of contaminated soil/sediment (Ayangbenro and Babalola 2017), modeling the future trend of heavy metal loading in soil/sediment, and reduce metal bioavailability to the biotic such as liming or addition of biochar to the soil/sediment (Bian et al. 2013, 2014). As an intense human activity found in both areas, it is necessary to increase transparency by improving and updating information on different heavy metal concentrations in order to establish a framework for proper management and control by authorities. Besides, investigation of the sources of pollution (either point or non-point source) during CBA or GBA development and management together with consideration of abiotic (soil)-biotic (organisms) interactions should be taken into account when choosing suitable remediation strategies in the future.

Author contributions Ho Man Leung analyzed the data and was a major contributor in writing the manuscript.
  Kwai Chung Cheung provided guidance on statistical analysis.
  Chi Kin Au provided interpretation to the data.
  Ken Kin Lam Yung organized the plan of research.
  Wai Chin Li organized the plan of research.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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