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Characteristics of Industrial Wastewater discharged from Industrialized Provinces and Specific Industrial Sectors in China based on the Official Statistical Reports

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In the last two decades, China has struggled with a lot of heavy metal pollution problems, which are mainly caused by the period of high economic growth. Therefore, effective preliminary measures, including low cost treatment techniques should be established in order to achieve development of industrial activity without serious heavy metal pollutions, since we cannot consider separately these two factors; industrial development and heavy metal pollution. Challenges to realization of the industrial development without serious heavy metal pollution by Chinese government as a representative of developing country will have positive impacts on many would-be developed countries.

Keywords: heavy metal pollution, remediation, industrial wastewater, industrial development, developing country, China.

1. Introduction

Heavy metals have been used for many different purposes, especially for development of industry, for thousands of years. They are also essential as trace elements for human bodies, plants and other living organisms. Highly concentrated heavy metals, however, are toxic for them, especially for humans, causing intellectual and developmental disabilities. Heavy metals are generally not biodegradable, and therefore, are often involved in the natural food chain as bio-magnification, consequently inducing their accumulation in human body. Furthermore, several elements; lead, hexavalent chromium, arsenic, cadmium, and mercury, are classified as strong human carcinogens by the International Agency for Research on Cancer¹⁾.

Heavy metals are often contaminated into the surrounding environments through several roots, e.g., natural phenomena and human causes. Heavy metal contaminations to natural environments are mainly caused by human activities, especially by mining operation and discharge of wastewater from heavy metal-related industry^{2, 3)}. In mining sites, heavy metal pollutions often remain in the field for over 50-100 years even after mining activity has been over. Another human-caused heavy metal contamination problems are the polluted environments by industrial wastewater. Since industrial factories manufacturing metal-containing and other related products, often deal with relatively large amount of heavy metals, serious

contamination problems may occur: Industrial wastewater containing heavy metals sometimes leaks accidentally or illegally to surrounding environments; soil, river and ground water. In Spain, several heavy metals, such as lead, mercury, chromium, cadmium, and arsenic, were released and contaminated into the atmosphere, ground water and soil, near a new hazardous waste incinerator (Constantí, Catalonia, Spain)⁴⁾.

In order to properly manage and control heavy metal pollution problems, it seems to be important to understand the wastewater management system of heavy metals-related industrial sectors since the pollution problems mostly accompanied with the industrial activities. In the last two decades, China has continuously suffered from a number of domestic heavy metal pollutions, as one of the highly industrialized developing countries. Therefore, China was chosen in this work as an example to study characteristics of industrial wastewater discharged in China.

The remainder of this article is organized as follows. Section 2 provides an overview of heavy metal pollutions in China. Section 3 and 4 discuss heavy metals discharged into industrial wastewater based on the national statistical data. In section 5, policies for heavy metal pollutions in China are described, followed by concluding remarks in Section 6.

Table 1: Pollution status in specific areas in China⁷⁾ (referred under the permission of DOWA eco-system Co., Ltd.).

Surveyed area	Pollution status				Total (%)	
	Slight (%)	Mild (%)	Moderate (%)	Severe (%)		
Agricultural area	13.7	2.8	1.8	1.1	19.4	
	Main contaminants: Cd, Ni, Cu, As, Hg, Pb					
Forest area	5.9	1.6	1.2	1.3	10.0	
	Main contaminants: As, Cd					
Grassland area	7.6	1.2	0.9	0.7	10.4	
	Main contaminants: Ni, Cd, As					
Unused area	8.4	1.1	0.9	1.0	11.4	
	Main contaminants: Ni, Cd					
Building area	Heavy metal industry site (5846 points of borehole)	-	-	-	-	36.3
		Industry type: Steel, non-ferrous metal, leather, papermaking, oil, coal, medicine, chemical fiber, mineral product, metal product,				
	Factory ruin (775 points of borehole)	-	-	-	-	34.9
		Industry type: Chemical industry, mining industry, metallurgy Main contaminants: Zn, Hg, Pb, Cd, As				
	Industrial park (2523 points of borehole)	-	-	-	-	29.4
		Industry type: Metal refinery, chemical factory Main contaminants: Cd, Pb, Cu, Zn, As				
	Mining site (1672 points of borehole)	-	-	-	-	33.4
	Main contaminants: Cd, Pb, As					
Irrigation site (1378 points of borehole)	-	-	-	-	26.4	
	Main contaminants: Cd, As					
Bothsides of highway (1578 points of borehole)	-	-	-	-	20.3	
	Main contaminants: Pb, Zn, As					

“Slight”; The standard < pollutant content ≤ 2× the standard, “Mild”; 2× the standard < pollutant content ≤ 3× the standard, “Moderate”; 3× the standard < pollutant content ≤ 5× the standard, “Severe”; 5× the standard < pollutant content

2. Heavy metal pollutions in China

2.1 Critical heavy metal species

Heavy metals have caused a number of environmental pollution problems in both water and soil, and finally human health damages, for the last twenty years in China. More than 1.5 million sites have been found to be contaminated by heavy metals in 2011 in China, according to the national census of environmental pollution in China. Following heavy metal species; hexavalent chromium (Cr(VI)), arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb) are classified to critical heavy metal pollutants in China by Ministry of Environmental Protection in China (MEPC), since they are categorized as strong human carcinogens as is mentioned previously. Central government has, therefore, mainly targeted these critical heavy metals to manage and control the situation of their discharges and contaminations.

2.2 Soil contamination by heavy metals in China

Central government of China has continuously struggled to solve heavy metal contamination problems, mainly caused by domestic industrial activities, over the past 20 years. However, heavy metal pollutions in agricultural areas caused by industrial activities and their ruins have been also concerned by Chinese people. In 2013, cadmium-contaminated rice has been recognized one of the most critical problems in China. Brigden et al. (2014) reported that rice samples collected from different locations in Hunan province were highly contaminated

not only by cadmium but also by arsenic and lead⁵⁾. Concentrations of cadmium in those rice samples were found to exceed the maximum allowable level in rice for human consumption (0.2 mg/kg)⁶⁾. The highest concentration of cadmium in a rice sample was 4.39 mg/kg, approximately 22 times to the standard. Since cadmium is strong human carcinogen, and accumulated in human body, continuous intake of cadmium-contaminated rice potentially causes permanent intellectual and developmental disabilities.

Many people having an awareness of the above problem requested of the government to investigate and publish environmental survey data. The environmental pollution survey had been ordered by the State Council in China to investigate domestic soil pollutions, and it had been carried out from April, 2005 to December, 2013 in the whole China except for Hong Kong and Xiamen. It was published online by Ministry of Environmental Protection in China on April, 2014 (Table 1). Soil contaminations were found in 16.1% of the whole investigation fields (slight contamination; 11.2%, mild; 2.3%, moderate; 1.5%, severe; 1.1%), and furthermore, 82.2% of its contamination was derived from heavy metals. Four of the five critical heavy metal species; cadmium, arsenic, lead and mercury, were found as main contaminants at almost all the contaminated fields. Especially, heavy metal pollutions were found at approximately 29-36% of the industrial activity-related “building area”, implying illegal discharges or unexpected leakages of industrial wastewater containing heavy metals into surface soil and water. Moreover,

19.4% of the agricultural area investigated in this survey, was found to be polluted by several heavy metals, including the above critical heavy metal species, which is serious situation since heavy metal pollution at agricultural field directly affects health of human. Central government of China stated that the spreading of heavy metal pollutions in China would be due to re-utilization of heavy metal-contaminated soils to constructions for agricultural purposes, causing a secondary contamination. In order to prevent the

spreading of heavy metal pollutions through secondary contamination, (1) industrial company and related production/manufacture firms should be required to completely manage industrial wastewater or waste solid containing heavy metals, and (2) re-utilization of soils should be strictly regulated by rules or laws. In China, the standards of hexavalent chromium, lead, and cadmium for agricultural surface water are unexpectedly twice higher than those for industrial discharge. This is one of the rules that should be improved.

Table 2a: Amount of heavy metals discharged into industrial wastewater from specific industrial sectors in China in 2006⁹⁾.

Industrial sectors	Heavy metals discharged into industrial wastewater									
	Mercury		Cadmium		Hexavalent chromium		Lead		Arsenic	
	(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)
Mining and Processing of Non-ferrous Metal Ores	0.14	5.3	11.6	19.0	2.3	2.2	121.9	32.2	19.2	4.2
Smelting and Pressing of Ferrous Metals	0.037	1.4	1.6	2.6	10.4	9.9	65.5	17.3	3.42	0.76
Smelting and Pressing of Non-ferrous Metals	0.84	31.1	41.5	68.0	12.2	11.6	137.6	36.4	289.7	64.1
Manufacture of Leather, Fur, Feather and Related Products	-	-	0.018	0.029	21.4	20.3	-	-	-	-
Manufacture of Raw Chemical Materials and Chemical Products	1.4	51.8	4.3	7.0	6.4	6.1	31.5	8.3	101.3	22.4
Manufacture of Metal Products	0.006	0.22	0.62	1.0	30.9	29.3	1.82	0.48	0.97	0.21
Manufacture of Transport Equipment	0.001	0.037	0.058	0.10	5.6	5.3	0.52	0.14	0.040	0.009
Production and Distribution of Electric Power and Heat Power	0.001	0.037	0.35	0.58	1.3	1.2	1.78	0.47	30.0	6.6
National total	2.7	-	61.0	-	105.6	-	378.3	-	452.2	-

Table 2b: Amount of industrial wastewater discharged from specific industrial sectors in China in 2006⁹⁾.

Industrial sectors	Amount of industrial wastewater discharged				
	Total amount	The amount exceeding discharge standards	[C]/[A]	[C]/[D]	[C]/[B]
	(10 ⁶ tons) [A]	(10 ⁶ tons) [C]	(%)	(%)	(%)
Mining and Processing of Non-ferrous Metal Ores	311	31	10.0	1.8	0.14
Smelting and Pressing of Ferrous Metals	1699	60	3.5	3.5	0.28
Smelting and Pressing of Non-ferrous Metals	337	46	13.6	2.7	0.21
Manufacture of Leather, Fur, Feather and Related Products	183	11	6.2	0.67	0.05
Manufacture of Raw Chemical Materials and Chemical Products	3391	271	8.0	15.9	1.3
Manufacture of Metal Products	211	10	4.9	0.60	0.05
Manufacture of Transport Equipment	247	15	5.9	0.86	0.07
Production and Distribution of Electric Power and Heat Power	2511	43	1.7	2.5	0.20
National total	21598 [B]	1702 [D]	7.9	-	-

3. Statistical analysis of heavy metals discharged into industrial wastewater

3.1 Specific industrial sectors discharging the critical heavy metals in China

Central government officially published online the “China Environmental Statistical Yearbook 2006” based on the survey in almost the whole country. In the chapter of “the freshwater environment” of the report, the amount of the five critical heavy metal species; mercury, cadmium, hexavalent chromium, lead, and arsenic, discharged into industrial wastewater from several industrial sectors in 2005, were published. Data from industrial sectors which were found to discharge relatively large amount of heavy metals, were partially extracted and summarized in Table 2a. Large amount of heavy metals was discharged from specific industrial sectors. Cadmium and lead are likely mining processing-related metal pollutants: Approximately 19% of cadmium and 32% of lead discharged into wastewater

in China were found to be from “mining and processing of non-ferrous metal ores”, indicating that these heavy metals were discharged during the mining activity and the following mineral processing. Ten percent of the amount of wastewater from this industrial sector was found to exceed the discharge standards, causing a risk of generation of heavy metal pollutions in surrounding environments and the following human disabilities (Table 2b).

Somewhat surprisingly, the industrial sector, “smelting and pressing of non-ferrous metals” was reported to discharge large amount of heavy metals; approximately 31% of mercury, 68% of cadmium, 12% of hexavalent chromium, 36% of lead, and 64% of arsenic into wastewater (Table 2a). This might be because that these heavy metals are often accompanied with non-ferrous metal concentrates, such as primary copper sulfides, and these impurities are removed during the metallurgical process. This tendency is particularly strong for arsenic and lead, causing large amount of arsenic and lead

discharges from “smelting and pressing of non-ferrous metals”; approximately 290 or 140 tons,
Table 3a: Amount of heavy metals discharged into industrial wastewater in industrialized provinces in China in 2006⁹⁾.

		Heavy metals discharged into industrial wastewater									
Region	Province	Mercury		Cadmium		Hexavalent chromium		Lead		Arsenic	
		(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)
<i>Northern</i>		<u>0.16</u>	<u>5.9</u>	<u>0.91</u>	<u>1.5</u>	<u>5.4</u>	<u>5.1</u>	<u>20.7</u>	<u>5.5</u>	<u>5.8</u>	<u>1.3</u>
<i>Northeastern</i>		<u>0.08</u>	<u>3.0</u>	<u>2.0</u>	<u>3.2</u>	<u>3.7</u>	<u>3.5</u>	<u>5.4</u>	<u>1.4</u>	<u>3.0</u>	<u>0.7</u>
<i>Eastern</i>		<u>0.13</u>	<u>4.8</u>	<u>4.2</u>	<u>6.8</u>	<u>36.9</u>	<u>34.9</u>	<u>43.0</u>	<u>11.4</u>	<u>36.4</u>	<u>8.0</u>
	Jiangsu	0.05	1.9	0.27	0.44	11.5	10.9	20.8	5.5	4.2	0.92
	Zhejiang	0.01	0.37	0.48	0.77	16.5	15.6	3.4	0.90	1.1	0.25
	Jiangxi	0.03	1.1	2.9	4.7	1.8	1.7	10.4	2.8	22.7	5.0
<i>Central and Southern</i>		<u>1.9</u>	<u>69.1</u>	<u>28.8</u>	<u>46.3</u>	<u>38.1</u>	<u>36.0</u>	<u>151.3</u>	<u>40.0</u>	<u>118.8</u>	<u>26.2</u>
	Hubei	0.03	1.1	0.60	0.97	4.6	4.3	5.3	1.4	6.1	1.4
	Hunan	1.6	58.7	19.9	32.1	16.9	16.0	92.2	24.4	93.5	20.6
	Guangdong	0.10	3.7	1.9	3.1	10.8	10.2	21.1	5.6	4.4	1.0
	Guangxi	0.06	2.2	6.1	9.8	1.3	1.2	28.3	7.5	13.2	2.9
<i>Southwestern</i>		<u>0.12</u>	<u>4.5</u>	<u>4.5</u>	<u>7.2</u>	<u>18.5</u>	<u>17.5</u>	<u>46.2</u>	<u>12.2</u>	<u>34.2</u>	<u>7.6</u>
	Sichuan	0.09	3.3	1.2	1.9	13.9	13.2	4.8	1.3	2.9	0.64
	Yunnan	0.02	0.74	3.2	5.1	0.07	0.07	37.0	9.8	5.9	1.3
<i>Northwestern</i>		<u>0.35</u>	<u>13.0</u>	<u>21.7</u>	<u>35.0</u>	<u>3.2</u>	<u>3.0</u>	<u>111.7</u>	<u>29.5</u>	<u>254.9</u>	<u>56.3</u>
	Shaanxi			0.42	0.68	1.4	1.33	5.1	1.4	1.5	0.32
	Gansu	0.27	10.0	19.8	31.8	1.0	0.93	82.0	21.7	250.8	55.3
National total		2.7		62.1		105.6		378.3		453.2	

Table 3b: Amount of heavy metals discharged into industrial wastewater in industrialized provinces in China in 2011¹⁰⁾.

		Heavy metals discharged into industrial wastewater									
Region	Province	Mercury		Cadmium		Hexavalent chromium		Lead		Arsenic	
		(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)	(tons)	(%)
<i>Northern</i>		<u>0.06</u>	<u>2.0</u>	<u>1.4</u>	<u>4.0</u>	<u>4.1</u>	<u>3.9</u>	<u>6.0</u>	<u>3.8</u>	<u>5.4</u>	<u>3.7</u>
<i>Northeastern</i>		<u>0.02</u>	<u>0.70</u>	<u>0.14</u>	<u>0.38</u>	<u>0.79</u>	<u>0.74</u>	<u>1.3</u>	<u>0.83</u>	<u>1.6</u>	<u>1.1</u>
<i>Eastern</i>		<u>1.8</u>	<u>65.4</u>	<u>5.5</u>	<u>15.4</u>	<u>43.2</u>	<u>40.6</u>	<u>23.0</u>	<u>14.8</u>	<u>22.8</u>	<u>15.5</u>
	Jiangsu	0.10	3.5	0.15	0.41	5.4	5.1	3.6	2.3	0.80	0.55
	Zhejiang	0.10	3.5	0.28	0.78	10.0	9.4	0.57	0.37	0.22	0.15
	Jiangxi	1.5	54.3	2.8	7.8	17.4	16.3	9.4	6.1	10.9	7.4
<i>Central and Southern</i>		<u>0.68</u>	<u>24.0</u>	<u>21.8</u>	<u>60.7</u>	<u>53.9</u>	<u>50.6</u>	<u>81.0</u>	<u>52.1</u>	<u>80.9</u>	<u>55.2</u>
	Hubei	0.22	7.9	0.85	2.4	16.6	15.6	4.2	2.7	12.0	8.2
	Hunan	0.28	9.9	14.5	40.4	3.3	3.1	42.5	27.4	55.7	38.0
	Guangdong	0.07	2.3	1.1	3.2	28.0	26.3	11.5	7.4	2.3	1.6
	Guangxi	0.08	2.9	2.5	7.0	4.3	4.0	15.6	10.1	9.1	6.2
<i>Southwestern</i>		<u>0.17</u>	<u>6.1</u>	<u>3.7</u>	<u>10.2</u>	<u>1.1</u>	<u>1.0</u>	<u>30.4</u>	<u>19.6</u>	<u>23.9</u>	<u>16.3</u>
	Sichuan	0.07	2.5	0.18	0.51	0.54	0.51	1.8	1.1	3.6	2.5
	Yunnan	0.06	2.0	3.3	9.3	0.05	0.04	27.9	18.0	15.6	10.6
<i>Northwestern</i>		<u>0.14</u>	<u>5.1</u>	<u>12.0</u>	<u>33.5</u>	<u>3.3</u>	<u>3.1</u>	<u>13.6</u>	<u>8.8</u>	<u>11.7</u>	<u>7.9</u>
	Shaanxi	0.03	1.2	9.7	26.9	0.26	0.25	4.2	2.7	1.0	0.66
	Gansu	0.07	2.6	1.4	4.0	0.24	0.23	6.9	4.4	5.7	3.9
National total		2.8		35.9		106.4		155.2		146.6	

respectively, in 2006 among the critical heavy metals. Therefore, this industrial sector may potentially cause heavy metal pollution problems around the processing sites. As for hexavalent chromium, it was found to be specifically discharged from “manufacture of leather, fur, feather and related products” and “manufacture of metal products”, since the heavy metal is often used for leather tanning and metal plating in chemical processing. Although only 8% of wastewater discharged from “manufacture of raw chemical materials and chemical products”, exceeded the discharge standards, it accounted for 16% share ([C]/[D] in Table 2b) of the amount of industrial wastewater exceeding discharge standards, and furthermore, 1.3% share ([C]/[B] in Table 2b) of the national total amount of industrial wastewater, due to its large amount of industrial wastewater in that industrial sector (Table 2b). In 2011, Ministry of Environmental Protection of China (MEPC) mentioned also that the major exposure sources of lead, mercury, chromium, cadmium, arsenic, and other heavy metal pollutions especially in agricultural fields in China, are involved in several industries, such as the manufacture of chemical materials and products, ferrous/non-ferrous metal smelting and rolling processing industry, manufacture of fabricated metal products, the electroplating industry, and the mining development⁸⁾.

3.2 Discharge distribution of the critical heavy metals in provinces and cities in China

Central government of China had also conducted investigations of province-based discharge distribution of the critical heavy metals. Lead and arsenic were found to be discharged in a large amount; approximately 450 and 380 tons, respectively, in China in 2005, while that of mercury was only 2.7 tons (Table 3a). The significant difference in the waste amounts among the heavy metal species might be due to its utilization or contamination level as unwanted products: Arsenic and lead are generally by-products often accompanying with non-ferrous minerals in relatively high contents ratio, while the content of mercury in such kind of minerals is quite low compared with that of the formers.

Northern and northeastern regions were found to account for only 0.7-5.9% shares in the national total discharges of the critical heavy metals. On the other hand, big shares of the amount of the heavy metals discharged into industrial wastewater were shown in Hunan province; approximately 59% for mercury, 32% for cadmium, 16% for hexavalent chromium, 24% for lead, and 21% for arsenic. Similar levels of the shares (except for hexavalent chromium) were also shown in Gansu province. The reason for the fact seems be the industrialization by mining industry, metallurgical industry, smelting and pressing ferrous/non-ferrous metal industry, and chemical industry: A lot of heavy metal industries have been established and developed in the both provinces because of the rich mineral deposits. In

recent years, Hunan province has become a base for relocation of manufacturing industries from such provinces as Guangdong, Zhejiang, Beijing, Fujian and Shanghai, may causing relatively big share of hexavalent chromium discharged into industrial wastewater in its national total amount.

Comparing the amount of heavy metals discharged between in 2005 and 2010, national total discharge amounts of cadmium, lead, and arsenic were dramatically reduced (reduction rate; 42% for cadmium, 59% for lead, 68% for arsenic), while those in mercury and hexavalent chromium were rather increased a bit than reduced (Table 3a, b). This reduction behavior in the national total amounts of these heavy metals might be resulted by the significant reduction of those in Hunan province (reduction rate; 83% for mercury, 27% for cadmium, 80% for hexavalent chromium, 54% for lead, 40% for arsenic) and Gansu province (reduction rate; 74% for mercury, 93% for cadmium, 76% for hexavalent chromium, 92% for lead, 98% for arsenic). This implies that heavy metal treatment techniques in the industrial parks in the both provinces, could be developed. Though the amount of mercury and hexavalent chromium discharged reduced in the both provinces, increases in those amount were reported in Jiangxi province, resulting in unchanged national total amount of those heavy metals discharged.

4. Specific industrial sectors discharging the critical heavy metals in Hubei province

Hubei province which locates on central and southern region, is one of the industrialized provinces in China. The amount of hexavalent chromium discharged into industrial wastewater in Hubei province increased from 4.6 to 16.6 tons in 2005 to in 2010, respectively (Table 3a, b). Other than that, those amount of mercury, cadmium, and arsenic also increased in the province in the five years. Table 4 shows the amount of heavy metals discharged into industrial wastewater from specific industrial sectors in Hubei province in 2011 and their concentrations in the wastewater are described. Huge amount of chromium was discharged from “ferrous metal smelting and rolling processing industry”, “manufacture of fabricated metal industry” and “electroplating industry” mostly in the form of hexavalent chromium, extremely toxic due to its strong oxidizing capacity compared with trivalent chromium. However, “ferrous metal smelting and rolling processing industry” discharged relatively large amount of industrial wastewater compared with the other two industries, resulting in its concentration meeting the discharge standard for hexavalent chromium in industrial wastewater in China (50 ppb as hexavalent chromium)¹¹⁾. On the other hand, its concentration in wastewaters discharged from the other two industrial sectors were

found to exceed the discharge standard of hexavalent chromium between 7-14 times.

“Non-ferrous metal smelting and rolling processing industry”, one of the mining-related industrial sectors, discharged industrial wastewater containing mercury, cadmium, lead, and arsenic with their excessive concentrations between 1.5-18 times to their discharge

standards (arsenic; 100 ppb, lead; 50 ppb, cadmium; 5 ppb, and mercury; 1 ppb)¹¹⁾. Although penalty is imposed to firms that discharged wastewater containing excessive concentrations of heavy metals to their discharge standards, improvement of treatment process seems to be effective to achieve industrialized society developed by environmentally friendly-industrial companies.

Table 4: Amount of heavy metal pollutants discharged into industrial wastewater in Hubei province in 2006^{8, 9)}.

Industrial sectors	Industrial wastewater containing heavy metals (10 ⁶ tons)	Amount of heavy metals discharged into industrial wastewater and its concentration in each industrial wastewater											
		Mercury		Cadmium		Hexavalent chromium		Total chromium		Lead		Arsenic	
		(kg)	(ppb)	(kg)	(ppb)	(kg)	(ppb)	(kg)	(ppb)	(kg)	(ppb)	(kg)	(ppb)
Mining industry	129	4.5	0.03	131.6	1.0	3.9	0.03	4.0	0.03	557.0	4.3	2630.0	20
Non-ferrous metal smelting and rolling processing industry	5.6	8.4	1.5	510.2	91.3	1.3	0.23	1.3	0.23	1870.3	335	2567.7	459
Ferrous metal smelting and rolling processing industry	239	-	-	0.10	0.0004	1724	7.2	1724	7.2	0.10	0.0004	-	-
Manufacture of raw chemical materials and chemical products	187	9.6	0.05	0.70	0.004	61	0.33	221	1.2	5.4	0.03	9988.3	53
Manufacture of fabricated metal products	9.0	-	-	-	-	6132	678	6133	678	945.4	105	-	-
Electroplating industry	25	-	-	3.2	0.13	8629	351	8630	351	46.2	1.9	-	-

5. Policies for heavy metal pollution in China

5.1 Financial supports and nationwide projects by the central government for the domestic heavy metal contaminations

Frequent heavy metal contamination incidents had been reported in China since 2009, causing extensive public concern. Over 40 serious heavy metal pollutions had been reported since 2010 by the official statistics. Therefore, Ministry of Environmental Protection of China told the media on July 2nd, 2015 that the central government had allocated about 2.8 billion yuan of special funds to support 30 prefectural cities in accelerating the integrated management of heavy metal contaminations. Following two incidents are examples of the heavy metal pollutions described above. In August, 2011, “Luliang Chemicals”; a chemical corporate in southwestern region, had dumped 5000 tons of toxic chromium tailing near a river in Yuezhou, Yunan province, causing contamination of chromium into the drinking water source for over 10 million people¹²⁾. This incident attracted a lot of media attention in the whole country. In May, 2013, contamination of cadmium to rice samples and its products had been announced by the Food and Drug Administration of Guangzhou, Guangzhou province¹³⁾. Over 40% of the rice products from the market in the city were found to be contaminated with cadmium in the concentration of over 0.4 mg as Cd/kg as rice. Note that the allowable concentration for cadmium in rice is 0.2 mg/kg in China, based on the national standards for food.

In 2010, the central government of China established special funds dedicated to the prevention and control of domestic heavy metal contamination. Ministry of Environmental Protection and Ministry of Finance decided to give financial supports for three consecutive years to top 30 prefectural cities for managing heavy metal pollution from the perspective of the urgency of

Table 5: List of the key prefectural cities to be supported by central government special funds in 2015¹⁴⁾.

Ranking	City	Province
1	Baiyin	Gansu
2	Changde	Hunan
3	Xiangtan	Hunan
4	Loudi	Hunan
5	Huzhou	Zhejiang
6	Liangshan Prefecture	Sichuan
7	Hechi	Guangxi
8	Jingmen	Hubei
9	Weinan	Shaanxi
10	Kunming	Yunnan
11	Ganzhou	Jiangxi
12	Shaoyang	Hunan
13	Xining	Qinghai
14	Yueyang	Hunan
15	Bijie	Guizhou
16	Yiyang	Hunan
17	Liupanshui	Guizhou
18	Haixi Prefecture	Qinghai
19	Hengyang	Hunan
20	Zhangjiajie	Hunan
21	Qujing	Yunnan
22	Dongguan	Guangdong
23	Xiangxi Prefecture	Hunan
24	Xiaogan	Hubei
25	Yantai	Shandong
26	Tongren	Guizhou
27	Changsha	Hunan
28	Dazu Prefecture	Chongqing
29	Shaoguan	Guangdong
30	Chenzhou	Hunan

the heavy metal control (Table 5). Eleven of all 30 cities locate on Hunan province including ten top industries, tobacco, steel, electricity, chemicals, nonferrous metals, building materials, transportation equipment, agricultural and sideline processing, specialized equipment manufacturing and petroleum processing industry. The reason for the fact seems to be that Hunan province has been actively industrialized due to its large mineral deposits, as is described in the previous section.

Ministry of Environmental Protection of China has published online a number of nationwide plans focusing on human health and environmental protection, such as “the national 10th five-year plan for environmental protection”, “special 10th five-year plans”, “the national 11th five-year plan for environmental protection”, and “the 12th five-year plan for the environmental health work of national environmental protection”. In 2016, MEPC publishes online “the 13th five-year plan”, stating the national plans for human health and environmental protection from 2016 to 2020. In the latest twelfth report so far, following three descriptions were found as present situation of environment and health work: (1) lack of baseline data became a bottleneck in addressing environment and health problems, (2) effective management instruments and methods to deal with environment and health problems are lacking, and (3) it is necessary for special organization to strengthen basic capacity in environmental health work¹⁰⁾. Since 1990s, no nationwide or regional large scaled investigation targeting environmental protection and human health has been conducted in China, and moreover, fundamental and continuous investigations and monitoring have not

been included in the routine work. Therefore, this resulted in un-clear baseline information on geographic distribution of the health impacts caused by serious environmental pollution and even degree of human health damage. Since a lot of attentions have been paid to heavy metal contamination problems and their countermeasures, special organization should be immediately established and illegal activity especially in industrial sites should be strictly controlled.

According to the report; “the 12th five-year plan”, they had mentioned that Chinese central government will primary establish a management team for environmental health work, detailed survey on environmental health issues in national key areas, in order to understand the status of the impacts of serious environmental problems on human health. Over 2.5 billion Chinese yuan had been, in total, invested to effectively execute the plans, as is shown in Table 6. The biggest budget had been accounted for survey on environmental health issues in order to understand the situation of environmental problems in China.

In the last decade, Chinese central government has continuously tried to understand the situations of domestic environmental pollutions and to manage and control them. Since China has a large territory, it may be hard task to completely manage domestic environmental pollutions. In order to achieve it as much as possible, all provinces of China are required to cooperate each other. In addition to that, stricter legal systems especially for both counter and preventive measures to environmental pollution problems, should be developed in each province.

Table 6: List of the key projects in the 12th five-year plan for the environmental health work of national environmental protection¹⁵⁾.

Key projects	Budget (10 ⁶ yuan)	Budget (%)
Survey on Environmental Health Issues	1850	73.1
Trial on Comprehensive Monitoring on Environmental Health	210	8.3
Development of Environmental Health Database and Information Management System	100	3.9
Development of Technical Supporting System for Environmental Health Investigation	92	3.6
Development of Technical Supporting System for Environmental Health Risk Assessment	60	2.4
Build Up a Technical System for Addressing Environmental Health Risk	30	1.2
Development of Laws and Regulations on Environmental Health	30	1.2
Development of Environmental Health Key Laboratory	40	1.6
Building Basic Capacity in Environmental Health	70	2.8
Environmental Health Publicity and Education Plan	50	2.0
Total investment	2532	100

5.2 Economic growth and heavy metal pollution problems

Increase in gross domestic product; GDP, is definitely the top priority of a nation. Due to the presence of many large mineral deposits in China's territory, its GDP has been significantly increased in the last two decades: Its environmental pollution problems, including illegal discharge of heavy metal-contaminated waste water, acid mine drainage problems in mining site, heavy metal contamination in ground soil and water at factory ruins, and secondary contamination of heavy metals to agricultural soils and other usages. These heavy metal-polluted situations cause human health damage.

Most developed countries had experienced environmental pollutions during their high economic growth period, which were mainly caused by human activities such as industrial operation and mining activity. In Japan, Minamata disease was one of the most serious heavy metal pollution accidents, which was caused by illegal discharge of industrial wastewater containing mercury compounds to Minamata bay in 1965. Once mercury is taken in human body through eating fish and shellfish those contaminated by the pollutants, it is accumulated and attacks the central nervous system, causing serious permanent human health damage.

In the high economic growth period, industrial companies deal with large amount of raw materials, obviously resulting in generation of larger amount of industrial wastewater containing heavy metals and other pollutants. Although industrial companies are responsible to keep a certain treatment efficiency of wastewater by investment in wastewater treatment sector especially in the high economic growth period, most of them often hesitate to do that. One of the reasons for this might be the fact that investment in wastewater treatment sector does not produce profits. Therefore, there should be some regulations about the treatment efficiency and its capacity since it is obvious that investment in wastewater treatment sector should be followed by that in production sector. In order to prevent heavy metal pollution problems caused by industrial activities in the high economic growth period especially in developing countries, the balance between making profits and keeping wastewater treatment efficiency is important. This is because that development of industrial activity, followed by increase in national GDP, is basically for maximization of a standard of living for human while keeping its health level.

Since treatment of industrial wastewater takes cost, development of treatment processes possibly operated with lower cost compared with conventional processes, is important. In general, there are two types of treatment process for heavy metal pollutions; active and passive treatment systems. Large amount of chemicals is used in the former to achieve quick treatment with relatively high cost, while long-term treatment is carried out with relatively low cost in the latter. In the case where contamination problem has already occurred with

GDP was approximately 730 billion USD in 1995, however, it was about 10 trillion USD, almost 14 times to that in 1995, in 2015. This dramatic change in GDP of China seemed to be owing to the development of domestic industrial activity. However, industrial development causes negative effects such as

concentrated heavy metals at an industrial site, an active treatment system may be suitable since immediate measure may be needed. On the other hand, in the case where heavy metals are contaminated but a mid- or long-term treatment is applicable, passive treatment system may be appropriate from the view point of treatment cost. Therefore, appropriate treatment systems should be chosen depending on the degree of emergency and the conditions of the heavy metal contaminations.

6. Conclusions

The characteristics of industrial wastewater discharged in China, one of the representative developing countries that suffer from serious heavy metal contamination problems, was studied in terms of province-based and industrial sector-based official statistical reports. The period of high economic growth, followed by increase in GDP, has ever been seen with development of industrial activities especially in highly industrialized developing countries such as China. Since 1990s, China has struggled with the domestic serious problems of heavy metal pollutions, especially contaminated by mercury, cadmium, hexavalent chromium, lead, and arsenic, all categorized to strong human carcinogens. According to various nationwide reports published by Ministry of Environmental Protection of China, approximately 30% of the industry-related sites in China was found to be contaminated by heavy metals, such as the above critical heavy metal species. Those heavy metal contaminations in China were found to be caused by specific industrial sectors. Highly developed provinces by mining-related industry and heavy metal industry, have discharged large amount of heavy metals including the critical heavy metals, into industrial wastewater, in some cases, with the concentrations exceeding discharge standards for the critical heavy metals. Since heavy metal pollution problems have been ever seen especially during the high economic growth period in most developed countries, it seems to not be easy to maintain balanced coexistence of industrial development and treatment for environmental pollutions during the period, although environmental pollution problems obviously give some negative effects on future increase in GDP from the economical viewpoint. However, since we cannot consider separately these two factors; industrial development and heavy metal pollution, effective preliminary measures should be established in order to achieve development of industrial activity without serious heavy metal pollution problems. Passive treatment systems based on wetland treatment, bioremediation, and phytoremediation, seem to be alternative approaches with lower management and

operation cost to the conventional active treatment systems. Challenges to realization of the industrial development without serious heavy metal pollution by China as a developing country, will surely have a positive impact on many would-be developed countries.

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