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Influence of activated-carbon-supported transition metals on the decomposition of polychlorobiphenyls. Part II: Chemical and physical characterization and mechanistic study

Yifei Sun [a, *], Lina Liu [b], Kazuyuki Oshita [c], Xiaolan Zeng [a], Wei Wang [d], Yibo Zhang [e]

[a] Beijing Key Laboratory of Bio-inspired Energy Materials and Devices, School of Space and Environment, Beihang University, Beijing, 100191, China
[b] School of Energy and Power Engineering, Beihang University, Beijing, 100191, China
[c] Graduate School of Global Environmental Studies, Kyoto University, Kyoto, 615-8540, Japan
[d] School of Environment, Tsinghua University, Beijing, 100084, China
[e] Central Research Institute of Building and Construction, MCC Group, Beijing, 100088, China

HIGHLIGHTS

- AC-supported transition metals (Ni, Cu, Zn, Fe) could destroy low-concentration PCBs.
- IRTM-C obtained a higher metal concentration and a better metal distribution on AC.
- IRTM-C had better effects on the decomposition of PCB-153 than LaTM-C.
- Ni, Cu, or Fe as electron donors in PCB dechlorination vs. the stability of Zn.
- Both temperature and chemical composition influenced PCB decomposition efficiency.

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ABSTRACT

This paper studies the synergism between transition metals (TMs) and activated carbon (AC) as a catalyst support used in the catalytic decomposition of PCBs. A series of AC-supported TM catalysts was prepared according to two distinct methods: impregnation and ion exchange which were defined as LaTM-C and IRTM-C, respectively. The catalytic reactions between 2,2′,4,4′,5,5′-hexachlorobiphenyl (PCB-153) and AC-supported Fe, Ni, Cu and Zn catalysts were conducted under N_2 atmosphere. Changes in the nature of the catalysts as well as the decomposition mechanism of PCB-153 are discussed. Important findings include: (i) a higher metal concentration and a better metal distribution on AC is realized using ion-exchange, despite a lower AC specific surface area, (ii) IRTM-C had better effects on the decomposition of PCB-153 than LaTM-C, (iii) the role of Ni, Cu, and Fe as electron donors in PCB dechlorination was evaluated vs. the stability of Zn, and (iv) both temperature and chemical composition of TM catalysts influenced the decomposition efficiency of PCBs.

1. Introduction

Polychlorinated biphenyls (PCBs) are highly stable compounds and exhibit excellent thermal properties, poor flammability and electrical conductivity, and high capacitivity. Since their commercial production beginning in 1929, they have been an important component in the insulation oil used in electrical transformers and capacitors due to the excellent electrical insulation property of PCBs (Wentz, 1989). PCBs persist in the environment and bioaccumulate in fatty tissues (Kelly and Gobas, 2001). Compared to dioxins, PCBs are only mildly toxic; still, some PCBs show dioxin-like toxicity. PCBs can also cause cancer in animals as well as serious non-cancer health effects, including effects on the immune system, the reproductive system, the nervous system, the endocrine system and other health effects (Qi et al., 2014). Especially the Yusho event (Yoshimura, 2003) and Yucheng event happened in Japan and

* Corresponding author.
E-mail address: sunif@buaa.edu.cn (Y. Sun).

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Taiwan (Rogan et al., 1988), their manufacture was halted in countries in the 1970s. However, a large fraction of the PCBs that were produced are still present in the environment (Lu et al., 2012). From 1930 through to 1970, the cumulative losses of PCBs to the environment were estimated at 354,000 tons (Ackerman et al., 1983). Due to poor storage conditions, the soil in the vicinity of the storage sites became highly contaminated, with the amounts of contaminated soil containing high (>500 ppm) and low (50–500 ppm) concentrations of PCBs estimated to be 50,000 and 500,000 tons, respectively (Chen et al., 2008).

In the 1980s, zero-valent metals were shown to act as reducers in the dechlorination of organic halogen compounds. This property has been widely exploited in environmental engineering (Fang and Al-Abed, 2008). Among zero-valent metals which can decompose

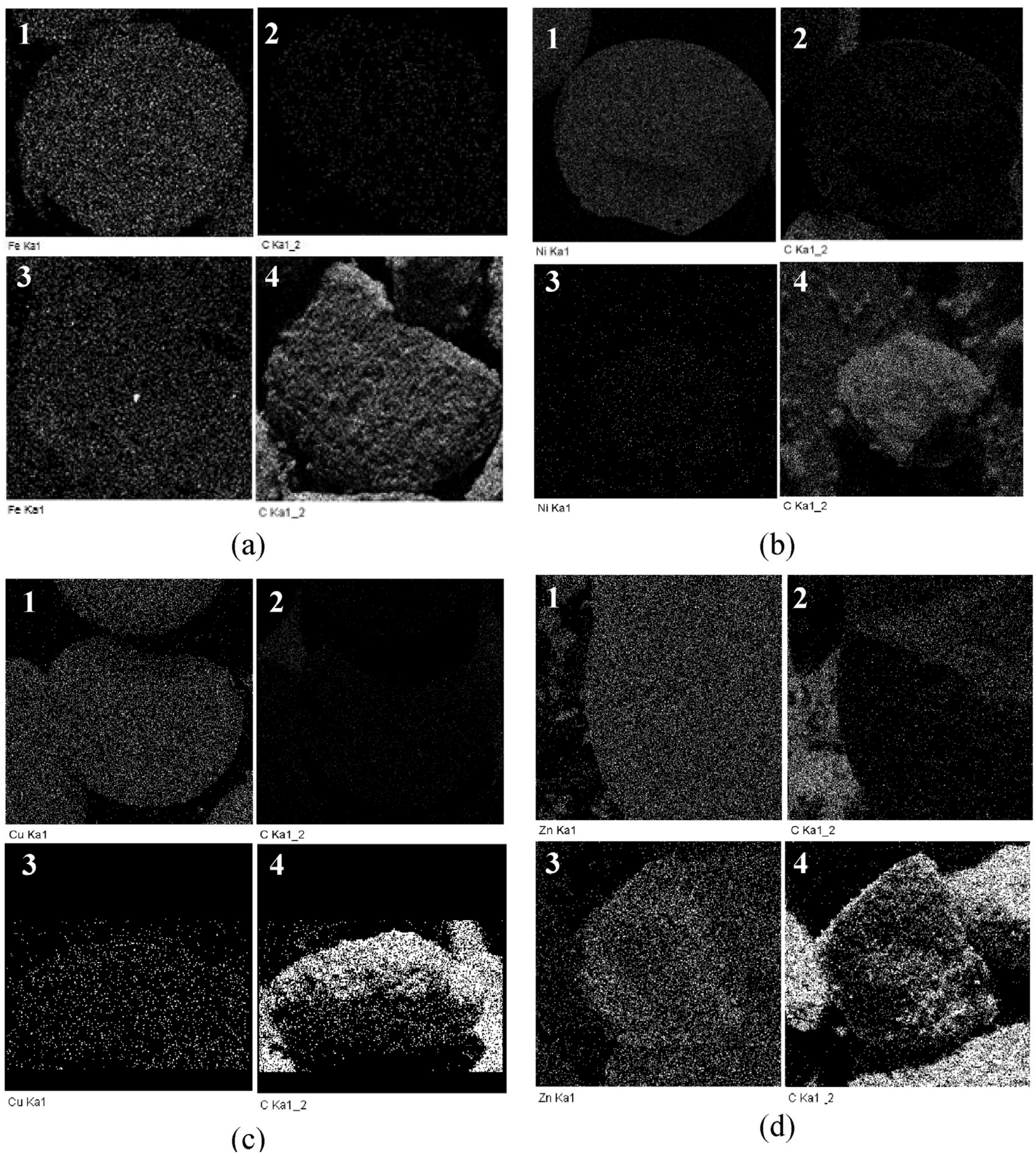

Fig. 1. SEM images of Fe-C, Ni-C, Cu-C and Zn-C. 1 and 2 shows the IRM-C of metal and C images; 3 and 4 shows the LaM-C of metal and C images. (a) Fe-C; (b) Ni-C; (c) Cu-C; and (d) Zn-C.

Table 1
Transition metal concentration on activated carbon of the 8 kinds of catalysts measured by ICP-AES.

Catalysts	Fe		Ni		Cu		Zn	
	IRFe-C	LaFe-C	IRNi-C	LaNi-C	IRCu-C	LaCu-C	IRZn-C	LaZn-C
TM concentration (mg/g-C)	374.0	45.1	542.5	12.0	557.3	12.9	502.8	46.0