



# Sub-lethal photocatalysis bactericidal technology cause longer persistence of antibiotic-resistance mutant and plasmid through the mechanism of reduced fitness cost

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## ABSTRACT

Antibiotic-resistance bacteria (ARB) sustain longevity in environments representing a public health threat recently, but some current bactericidal technologies could eliminate ARB at endpoint of treatment. However, the intermediate process, where bacterial community might be shaped by a complex array of external stressor, was less to be investigated. Herein, the sub-lethal photocatalysis (Sub-PC) bactericidal technology was first applied to validate its effects on the fitness cost and fate of ARB mediated by mutations and antibiotic-resistance gene (ARG) encoded plasmid. Results revealed that the fitness cost of both two types of ARB decreased under Sub-PC conditions as compared with Luria-Broth (LB) broth condition. Plate counting revealed that antibiotic resistance mutant exhibited 6–7 days longer maintenance under the Sub-PC conditions than that under the LB condition. Besides, for plasmid-encoded ARB, the average abundance of ARG in bacteria community was maintained at 0.38 copies for *ctx-1* and 0.58 copies for *mcr-1* under the Sub-PC condition, which were higher than that under the LB condition (0.29 copies for *ctx-1* and 0.45 copies for *mcr-1*). This study suggests that Sub-PC could cause longer-term maintenance of antibiotic resistance and provides an insightful understanding that how anthropogenic sterilization technologies or stressor may alleviate or spread bacterial antibiotic resistance.

## 1. Introduction

The persistence and dissemination of antibiotic-resistance bacteria (ARB) are problematic all over the world and represent a major public health threat recently [1–3]. It is well known that antibiotic resistance of bacteria can evolve via two pathways: chromosomal mutation and acquisition of mobile genetic element [4]. Usually, these processes occurred when certain selection pressures posed by sublethal level of antibiotics were emerging [5,6]. In the presence of antibiotics, the acquisition of antibiotic resistance provides a fitness advantage for ARB in comparison with antibiotic-susceptible competitors. Whereas, in the absence of antibiotics, the antibiotic resistance generally confers disadvantages to bacteria, typically observed as lower growth rate and reduced survival due to the changes in essential genes and/or altered resource usage which termed as fitness cost [7,8]. Based on the mechanism of fitness cost, it is suggested that bacteria should be generally

out-competed by more antibiotic susceptible and higher fitness populations after removing the selective pressure posed by the antibiotics [9,10]. However, after the reduction of clinical usage of some antibiotics, the prevalence of their corresponding resistances among *Escherichia coli* remained in environment [11].

Besides the antibiotics, bacterial communities may also be shaped by a complex array of environmental factors or stressors. It has been reported that, except antibiotics, some other stressors, such as low temperature, resource limitation, could reduce the fitness cost of rifampicin resistance bacterial mutations so that contribute to its persistence in environmental system [12,13]. Besides, different type of growth condition could also confer bacteria different fitness cost. For example, some antibiotic-resistance mutants have shown no fitness cost in laboratory medium but a high fitness cost in mice [14]. Furthermore, some environmental factors could also participate in bacterial adaptive trait, for example, pre-exposure to the stimulus that typically appeared

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# Micro/nano-bubble assisted synthesis of Au/TiO<sub>2</sub>@CNTs composite photocatalyst for photocatalytic degradation of gaseous styrene and its enhanced catalytic mechanism†

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A facile micro/nano-bubble method was firstly applied to synthesize an Au/TiO<sub>2</sub>@CNT composite photocatalyst for photocatalytic degradation of gaseous styrene. The morphologies, structures and compositions of the photocatalysts were investigated by using a series of analytical techniques (scanning and transmission electron microscopy, FT-IR spectroscopy, Raman spectroscopy, X-ray diffraction, and X-ray photoelectron spectroscopy). The micro/nano-bubbles can effectively facilitate the reaction of Au and TiO<sub>2</sub> NPs decorated onto CNTs, forming a stable ternary composite structure. The photocatalytic performance of Au/TiO<sub>2</sub>@CNTs was investigated by the methodology of central composite design (CCD) in response surface methodology (RSM). The photocatalytic degradation and mineralization of styrene over Au/TiO<sub>2</sub>@CNTs drastically increased with the rise of reaction temperature due to the formation of a compact structure. The analysis of EPR, UV-vis DRS, electrochemical properties and TPD-O<sub>2</sub> further revealed the enhanced photocatalytic mechanism of Au/TiO<sub>2</sub>@CNTs. The further identification of free radicals showed that the photocatalytic degradation and mineralization of styrene were closely related to oxidative radicals such as hydroxyl radicals and superoxide radicals, which were mainly attributed to the synergistic effects of Au NPs and CNTs to enhance the photocatalytic activity. This work will provide a new insight into designing photocatalysts with high photocatalytic performance and stability for the degradation of hazardous VOCs.

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## Environmental significance

In the field, photocatalytic oxidation in the presence of TiO<sub>2</sub> to give total or partial oxidation of gaseous contaminants to benign substances is one of the most promising environmentally friendly techniques for the abatement of volatile organic compounds (VOCs). However, TiO<sub>2</sub> has a wide band gap, high recombination rate of photogenerated electron/hole pairs and low specific surface area. In this work, physical micro/nano bubbles were used as a soft template to induce the synthesis of Au/TiO<sub>2</sub> NPs assembled with CNTs. On the basis of the experimental results of central composite design (CCD) in response surface methodology (RSM), the intrinsic connections between the photocatalytic properties of the Au/TiO<sub>2</sub>@CNT composite and various factors such as reaction temperature, the mass fraction of CNTs, the amount of HAuCl<sub>4</sub> and reaction time were systematically revealed. Furthermore, the influence of the structure and composition on the photocatalytic properties, recombination of photogenerated electron/hole pairs, electrochemical properties and free radical generation of the Au/TiO<sub>2</sub>@CNT composite was also discussed. Finally, a model of the photocatalyst system was carefully proposed to predict the migration and transformation mechanisms of photogenerated electron/hole pairs according to the obtained results.

## 1. Introduction

Photocatalytic oxidation has been extensively studied for air purification, such as the removal of volatile organic com-

pounds (VOCs).<sup>1–4</sup> Among various semiconductor materials, TiO<sub>2</sub> is one of the most promising photocatalysts for environmental purification owing to its low cost, nontoxicity, good stability, and excellent photocatalytic activity.<sup>5</sup> However, its wide band gap of 3.2 eV, high recombination rate of photogenerated electron/hole pairs and low specific surface area are obstacles for its industrial application. Many attempts have been already taken to improve the photocatalytic properties, and the main strategy is to fabricate a novel structure and improve the surface performance to obtain high-



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# Photocatalytic ozonation mechanism of gaseous *n*-hexane on MO<sub>x</sub>-TiO<sub>2</sub>-foam nickel composite (M = Cu, Mn, Ag): unveiling the role of <sup>•</sup>OH and <sup>•</sup>O<sub>2</sub><sup>−</sup>†

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Nanocomposites of MO<sub>x</sub>-TiO<sub>2</sub> (M = Cu, Mn, Ag) supported on foam nickel (MO<sub>x</sub>/TiFN) were successfully applied in the photocatalytic ozonation of gaseous alkane. All MO<sub>x</sub> samples presented nanoflake structures with two metal oxides, corresponding to Cu<sub>2</sub>O and CuO in CuO<sub>x</sub>, Mn<sub>2</sub>O<sub>3</sub> and MnO<sub>2</sub> in MnO<sub>x</sub>, and Ag and Ag<sub>2</sub>O in AgO<sub>x</sub>. These binary metal oxides composited with TiFN displayed 1.3 to 2.0 times higher degradation and mineralization efficiencies toward 350 ppmv of *n*-hexane than TiFN. The promoted <sup>•</sup>OH and <sup>•</sup>O<sub>2</sub><sup>−</sup> from O<sub>3</sub> conversion on MO<sub>x</sub> were responsible for the enhanced efficiency. And <sup>•</sup>O<sub>2</sub><sup>−</sup> made a higher contribution to the enhancement, since the relative amount of <sup>•</sup>O<sub>2</sub><sup>−</sup> increased by 3.2 to 7.9 times more than <sup>•</sup>OH after MO<sub>x</sub> composition. Our experimental and theoretical mechanism results further confirmed that both <sup>•</sup>OH and <sup>•</sup>O<sub>2</sub><sup>−</sup> were important for the epoxidation transformation of *n*-hexane on MO<sub>x</sub>/TiFN, while <sup>•</sup>OH dominated in the conversion of alcohol intermediates to corresponding radicals, and <sup>•</sup>O<sub>2</sub><sup>−</sup> determined the subsequent epoxidation transformations of these radicals to four epoxides with 3, 5 and 6 membered rings. The present work could provide deep insight into an enhanced mechanism for nanomaterial photocatalytic ozonation technology, and efficiently replenish alkane atmospheric transformation mechanisms.

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## Environmental significance

Nanomaterial photocatalytic ozonation is an effective technology for artificial alkane elimination, to avoid secondary pollution in the atmospheric environment and thus threats to human health. Reactive oxygen species (ROSS, such as <sup>•</sup>OH and <sup>•</sup>O<sub>2</sub><sup>−</sup>) from the decomposition of O<sub>3</sub> by metal oxide nanomaterials are considered to be responsible for high efficiency. The role of these ROSS in the promoted photocatalytic ozonation performance is still not fully understood. This study confirms that <sup>•</sup>O<sub>2</sub><sup>−</sup> makes a higher contribution to the enhancement than <sup>•</sup>OH, while <sup>•</sup>OH dominates in the conversion of alcohol intermediates to corresponding radicals, and <sup>•</sup>O<sub>2</sub><sup>−</sup> determines the subsequent epoxidation transformations of these radicals to four epoxides. The present work could provide deep insight into enhanced mechanisms for nanomaterial photocatalytic ozonation technology, and efficiently replenish alkane atmospheric transformation mechanisms.

## 1. Introduction

Alkanes are the most abundant artificially emitted volatile organic compounds (VOCs) with a percentage of about 40%.<sup>1</sup> These massively discharged alkanes are widely detected in the atmospheric environment,<sup>2–4</sup> where their oxidation leads to the formation of secondary pollutants, such as ozone and organic aerosols, profoundly impacting air quality, human

health, and climate.<sup>5–7</sup> Hence, efficiently controlling alkanes from anthropogenic emission sources is necessary to avoid their secondary pollution in the atmospheric environment and thus their threat to human health.

TiO<sub>2</sub> photocatalytic ozonation has been successfully applied for alkane elimination in the laboratory.<sup>8–15</sup> For example, Zhong *et al.* investigated the photocatalytic ozonation of 500 ppbv *n*-hexane on TiO<sub>2</sub>, and about 50% removal efficiency was obtained under optimum conditions,<sup>16</sup> while Zhang *et al.* reported an elimination of 45% for 1000 ppbv *n*-hexane by TiO<sub>2</sub> photocatalytic ozonation.<sup>17</sup> Clearly, these laboratory studies obtain only ≤50% removal efficiency toward ppbv-level alkanes, while the concentration of industry-emitted alkanes mostly ranges from several ppmv<sup>18</sup> to hundreds of ppmv,<sup>7</sup> indicating that further improvement in

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# The synergic degradation mechanism and photothermocatalytic mineralization of typical VOCs over PtCu/CeO<sub>2</sub> ordered porous catalysts under simulated solar irradiation

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## ABSTRACT

The major challenges facing catalysts for mineralization of volatile organic compounds (VOCs) include poor photocatalytic efficiency, high cost of thermocatalytic oxidation, and low stability. Here, a highly active and stable PtCu/CeO<sub>2</sub> ordered porous nanostructure catalyst was synthesized and efficiently applied in the instant mineralization of paraffinic VOCs under photothermocatalytic conditions. Optical and morphological characterization shows that low loadings of PtCu alloy clusters on CeO<sub>2</sub> surfaces lead to enhanced light harvesting, improved charge separation, and increased capacity for reactive oxygen generation and then promote a dynamic balance of Cu<sup>1+,2+</sup>/Cu<sup>0</sup> with high photothermocatalytic stability. Reaction kinetics calculations and carbon deposits investigation reveal that photothermocatalytic synergism mainly comes from the acceleration of the Mars–van Krevelen redox cycle by photocatalysis and the enhancement of coke resistance by thermocatalysis. The strategy here would provide insight into the design of highly effective catalysts, as well as in-depth understanding of the synergic mechanism of photothermocatalytic mineralization of refractory VOCs.

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## 1. Introduction

Straight-chain paraffinic volatile organic compounds (VOCs), such as n-pentane emitted from refinery and e-waste dismantling processes, are always hard to mineralization completely by a single catalysis technique, resulting in serious atmosphere pollution [1,2]. Current pursuit of more efficient and economical resolution for atmospheric issues has greatly promoted both the development of catalysts and the enhancement of catalytic reaction processes [3–5]. Though photocatalysis offers a viable opportunity for degrading low-concentration VOCs under mild conditions, most photocatalysts suffer from low quantum yield [6,7]. For example, only 15% of n-pentane can be mineralized over P25 after 365-nm UV illumination for 60 min [8]. Moreover, carbon deposits are prone to occur during photocatalytic processes, and coke accumulation would poison the active site of the catalyst, leading to low photocatalytic efficiency [9]. Thermocatalytic oxidation is another effective method for deep mineralization of VOCs, even changing coke into CO<sub>2</sub> [10,11]. However, this traditional thermocatalytic treatment alone also has some significant drawbacks, in that sup-

ported noble metal catalysts (more than 0.5 wt% Pt loading) and high temperature (more than 500 °C) are always required for effective operation in paraffinic VOCs mineralization, resulting in high energy costs [5,12,13].

Much research has suggested that combining thermocatalysis with photocatalysis to maximize synergistic effects could overcome their limitations [14–18]. Compared with traditional TiO<sub>2</sub> catalysts, nanostructured CeO<sub>2</sub> shows more efficiency in photothermocatalytic removal of VOCs, owing to its unique optical properties, remarkable Ce<sup>4+</sup>/Ce<sup>3+</sup> redox properties, high oxygen release/storage capacity, and favorable thermostability [16]. Considering that the catalytic reaction is a typical surface process, sufficient contact with VOCs and easy mass transfer facilitation can be realized over the ordered porous structures and improve the catalytic performance [19]. In addition, supported precious metals, especially Pt, have been well established as stabilizers of photoexcited electrons for suppressing charge recombination during photocatalytic processes [20] and highly active catalysts for activating both adsorbed oxygen and surface lattice oxygen to directly oxidize VOCs [21]. However, the coarsening of the noble metal particles and the sintering of the support, leading to the loss of active sites and irreversible deactivation, is an important concern for their application [10]. In comparison with single

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# High-concentration nitrogen removal coupling with bioelectric power generation by a self-sustaining algal-bacterial biocathode photo-bioelectrochemical system under daily light/dark cycle

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## HIGHLIGHTS

- Self-sustained power output and N removal in PBES were achieved by day/night cycle.
- Day/night cycle sustained high microbial diversity for power output and N removal.
- Daily light/dark cycle enable multi-approach N removal in algal-bacterial cathode.
- Content of N, P and TOC affect PBES performance mainly through alga activity.

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## ABSTRACT

High-concentration nitrogen removal coupled with bioelectric power generation in an algal-bacterial biocathode photo-bioelectrochemical system (PBES) was investigated. The PBES can self-sustaining operation with continuous power output under day/night cycle by alternately using photosynthetic dissolved oxygen and nitrate/nitrite as cathodic electron acceptors. The PBES generated a high maximum power of 110mw/m<sup>2</sup> under illumination and relatively lower power of 40mw/m<sup>2</sup> under dark. The bioelectricity generation was accompanied by high-concentration nitrogen removal in the algal-bacterial biocathode. The NH<sub>4</sub>-N was removed completely within 120 h while maximum NO<sub>3</sub>-N removal efficiency of 86% and maximum total nitrogen removal efficiency of 83% can be reached after 192 h at initial NH<sub>4</sub>-N concentration of 314 mg/L and NO<sub>3</sub>-N concentration of 330 mg/L. Combined processes of bio-electrochemical reduction and algal-bacterial interactions provided multiple approaches for nitrogen removal in the biocathode, including nitrifying using photosynthetic oxygen, bioelectrochemical denitrification using the cathode as electron donor, heterotrophic denitrification using photosynthetically produced dissolved organic matters as carbon source and algal-bacterial uptake. Accelerated nitrogen removal with simultaneously improved cathode performance was observed at high concentration of nitrogen and phosphate buffer due to enhanced algal activities for photosynthetic oxygen release and enhanced algal-bacterial interactions for nitrogen transformation. Addition of external organic carbon negatively affected nitrification and decreased cathode potential due to oxygen consumption by aerobic carbon oxidation but enhanced denitrification due to continuous release of high concentration of

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## Comparing pollution patterns and human exposure to atmospheric PBDEs and PCBs emitted from different e-waste dismantling processes



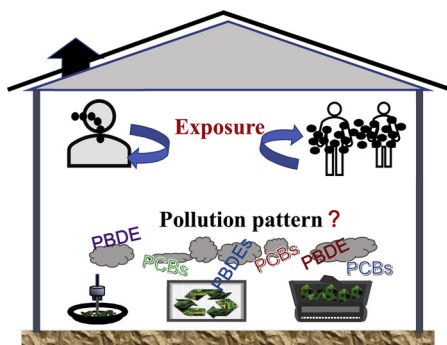
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### GRAPHICAL ABSTRACT



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### ABSTRACT

Waste electrical and electronic equipment (E-waste) recycling provides post-consumption economic opportunities, can also exert stress on environment and human health. This study investigated emissions, compositional profiles, and health risks associated with polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) at five workshops (electric blowers to treat mobile phones (EBMP), electric heating furnaces to treat televisions (EHFTV) and routers (EHFR), and rotatory incinerators to treat televisions (RITV) and hard disks (RIHD)) within an e-waste dismantling industrial park. Total suspended particulate (TSP), PBDE, and PCB concentrations were  $490\text{--}1530\ \mu\text{g m}^{-3}$ ,  $26.6\text{--}11,800\ \text{ng m}^{-3}$  and  $6.4\text{--}19.8\ \text{ng m}^{-3}$  in different workshops, respectively. Tetra-BDEs were dominant in TV recycling workshops, whereas deca-BDEs were in other workshops. BDE-47, -99, and -209 were the most abundant PBDEs during e-waste recycling activities (except in RIHD workshop). Penta-CBs were present at high levels in TV workshops, as were tetra-CBs in RIHD workshop. Low brominated BDEs contributed a large portion during working and non-working time. The percentages of octa-BDEs and nona-BDEs were higher during non-working than working time. PBDEs posed a higher non-cancer risk; PCBs posed cancer risk to workers through inhalation in TV workshops. This study provides insights into environmental characterization of PBDEs and PCBs during e-waste recycling processes.

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# Enhanced oxytetracycline removal coupling with increased power generation using a self-sustained photo-bioelectrochemical fuel cell

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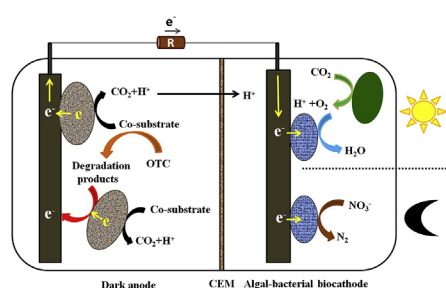
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## HIGHLIGHTS

- Simultaneous OTC removal and power generation in PBFC was firstly investigated.
- Bioelectrochemical enhanced co-metabolism responsible for OTC removal in bioanode.
- Power output of PBFC was significantly increased by feeding OTC to the bioanode.
- Degradation product of OTC mediated electron transfer from bacterial cell to anode.
- OTC-tolerant bacteria for degrading OTC and producing electricity were enriched.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Photo-bioelectrochemical fuel cell (PBFC) represents a promising technology for enhancing removal of antibiotic pollutants while simultaneously sustainable transformation of organic wastes and solar energy into electricity. In this study, simultaneous antibiotic removal and bioelectricity generation were investigated in a PBFC with daily light/dark cycle using oxytetracycline (OTC) as a model compound of antibiotic. The specific OTC removal rate increased by 61% at an external resistance of 50  $\Omega$  compared to that in the open-circuit control, which was attributed to bioelectrochemically enhanced co-metabolic degradation in the presence of the bioanode. The OTC removal was obviously accelerated during illumination of cathode in contrast with a dark cathode due to the higher driving force for anodic bioelectrochemical reaction by using photosynthetic oxygen as cathodic electron acceptor during illumination than that using nitrate in dark. The bioelectrocatalytic activity of anodic biofilm was continuously enhanced even at an initial OTC concentration of up to 50 mg L<sup>-1</sup>. The degradation products of OTC can function as mediators to facilitate the electron transfer from bacteria to the anode, resulting in 1.2, 1.76 and 1.8 fold increase in maximum power output when 10, 30 and 50 mg L<sup>-1</sup> OTC was fed to the

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# Photochemical degradation kinetics and mechanism of short-chain chlorinated paraffins in aqueous solution: A case of 1-chlorodecane<sup>☆</sup>

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## ABSTRACT

Short chain chlorinated paraffins (SCCPs) have attracted worldwide attention in recent years, due to their high production volume, persistent, bioaccumulative and toxic properties. In this study, 1-chlorodecane (CD) was selected as a model of SCCPs to explore its photochemical degradation behavior under UV irradiation. The results found that CD could be completely photochemical degradation within 120 min, and the  $\cdot\text{OH}$  was found to be the main reactive species from both quenching experiments and electron paramagnetic resonance (EPR) results. However, the contribution of triple excited state of CD ( $^3\text{CD}^*$ ) was still nonnegligible from the results with the absorption peak at 480 nm obtained by laser flash photolysis. Based on the identified intermediates as well as the data from theoretical chemical calculation, the detailed photochemical degradation mechanism of CD was tentatively proposed that CD firstly was excited and photo-ionized under UV irradiation, and the released  $\text{Cl}^*$  in water could result in generating  $\cdot\text{OH}$ . Then  $\cdot\text{OH}$  initiates CD degradation mainly through the H-abstraction pathway, leading to the generation of several dehydrogenation radicals, which further generated alcohols or long chain intermediates through radical-radical reactions. The results will provide a comprehensive understanding of the degradation mechanism and environmental fates of SCCPs in water under UV irradiation.

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## 1. Introduction

Short chain chlorinated paraffins (SCCPs) are extensively used as adhesives, metal-working fluids, sealants, paints, and leather finishing agents as well as plasticizers and flame retardants in rubbers and polymers (Gao et al., 2016c). SCCPs are high production volume chemicals with annual global production of approximately 165000 t (Gluge et al., 2016). There are increasing concerns over SCCPs owing to their persistence, great potential for long-range atmospheric transport, bioaccumulation in food webs, high toxicity to aquatic organisms and potentially carcinogenic property (Du et al., 2018; Sun et al., 2017; Tomy et al., 1999; Zeng et al., 2011; Zhou et al., 2018). In addition, SCCPs could affect the human immune system and reproductive system (Feo et al., 2009). As such, SCCPs have been recognized as new persistent organic pollutants (POPs) in May 2017 by the Stockholm Convention. Moreover, the

European Chemicals Agency also added SCCPs into the candidate list of substances of very high concern (Yuan et al., 2017).

SCCPs can be readily released into the environment during their production, industrial use, storage, and carry-off from manufactured products. Therefore, in the past decades, SCCPs have been frequently detected in various aquatic ecosystems worldwide such as Spain, UK, Japan, Canada as well as China (Feo et al., 2009; Gao et al., 2012; Houde et al., 2008; Zeng et al., 2012). Furthermore, due to the incomplete removal by current wastewater treatment technologies, SCCPs are released into the aquatic environment where they are (bio) degraded, bioaccumulated or biotransformed. Several transformation products of some organic compounds are found to be more toxic or persistent than their parental compounds, and thus pose higher risks to the environment (Cui et al., 2011; Gao et al., 2016a; Gao et al., 2016b; Liu et al., 2014). Previous report found that CPs could be dechlorinated and chlorine rearranged in the plant tissues (Li et al., 2017). The thermal decomposition of CPs would generate high PAHs and Cl-PAHs, generally defined as unintentionally produced POPs (Xin et al., 2017). Moreover, chlorinated olefins could be formed during the metal drilling and drilling, and they possibly together with CPs

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# Characterizing and optimizing (co-)pyrolysis as a function of different feedstocks, atmospheres, blend ratios, and heating rates

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## ABSTRACT

(Co-)pyrolysis behaviors were quantified using TG and Py-GC/MS analyses as a function of the two fuels of sewage sludge (SS) and water hyacinth (WH), five atmospheres, six blend ratios, and three heating rates. Co-pyrolysis performance, gaseous characterizations and optimization analyses were conducted. Relative to N<sub>2</sub> atmosphere, co-pyrolysis was inhibited at low temperatures in CO<sub>2</sub> atmosphere, while the CO<sub>2</sub> atmosphere at high temperatures promoted the vaporization of coke. The main (co-)pyrolysis products of SS and WH were benzene and its derivatives, as well as alkenes and heterocyclic compounds. Average apparent activation energy decreased gradually with the increased atmospheric CO<sub>2</sub> concentration and was highest (377.5 kJ/mol) in N<sub>2</sub> atmosphere and lowest (184.7 kJ/mol) in CO<sub>2</sub> atmosphere. Significant interaction effects on the mean responses of mass loss, derivative TG, and differential scanning calorimetry were found for fuel type by heating rate and atmosphere type by heating rate.

## 1. Introduction

The rapid generation rate of sewage sludge (SS) threatens environmental and public health due to its toxic and harmful contents (Liu et al., 2016, 2018). Currently, China is producing over  $4 \times 10^7$  tons of SS 80% of which does not meet the essential treatment requirements of harmlessness and stability (Huang et al., 2018) and is expected to exceed  $6 \times 10^7$  tons by 2025 (Guo and Dai, 2017). There is a growing change in the perception of sludge from an unwanted waste to a bioenergy resource, and thus, a growing need for a suitable thermal technology to be used in an environmentally and economically efficient way (Liu et al., 2015a,b). The present SS co-pyrolysis technology poses an effective method to recover resources, to avoid secondary pollutants, and to reduce dioxin and heavy metals (Raheem et al., 2018). However, the SS pyrolysis renders volatiles difficult to precipitate, thus inhibiting its large-scale applications (Raheem et al., 2018).

The co-pyrolysis performance of SS and different biomass materials in different ratios has been explored using thermogravimetric (TG) and pyrolysis-gas chromatography/mass spectrometric (Py-GC/MS) analyses. For example, Alvarez et al. (2015) concluded that the ash content

of SS promoted the formation of bio-oils due to its catalytic function. Lin et al. (2014) reported that oil palm waste improved the pyrolysis of paper mill sludge. Wang et al. (2016) found a significant synergistic effect during co-pyrolysis of sludge and wheat straw that in turn increased the pyrolysis performance and the production of gaseous and liquid products. Zhao et al. (2018) reported an enhanced co-pyrolysis performance of municipal sludge and hazelnut shells whose mechanism was best described by a stochastic nucleation growth model. Lin et al. (2017) stated that the co-pyrolysis products of municipal sludge and bagasse led to the gaseous products of mainly aromatic compounds. Fang et al. (2015) pointed out that co-pyrolysis of household garbage and paper mill sludge reduced activation energy ( $E_a$ ) value. However, there exists no study about the co-pyrolysis of WH using TG and Py-GC/MS analyses.

Water hyacinth (*Eichhornia crassipes*) (WH) has a widespread geographical distribution, a strong reproductive ability, and high (hemi) cellulose and low lignin contents which all render it suitable for energy generation (Gunnarsson et al., 2007; Biswas et al., 2017; Sindhu et al., 2017; Huang et al., 2018). WH pyrolysis process mainly involved the decomposition of (hemi)cellulose (Luo et al., 2011) leading to the

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# Genome sequence of a spore-laccase forming, BPA-degrading *Bacillus* sp. GZB isolated from an electronic-waste recycling site reveals insights into BPA degradation pathways

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## Abstract

Bisphenol A (BPA) is a synthetic chemical with known deleterious effects on biota. A genome sequencing project is an important starting point for designing a suitable BPA bioremediation process, because it provides valuable genomic information about the physiological, metabolic, and genetic potential of the microbes used for the treatment. This study explored genomic insights provided by the BPA-degrading strain *Bacillus* sp. GZB, previously isolated from electronic-waste-dismantling site. The GZB genome is a circular chromosome, comprised of a total of 4,077,007 bp with G+C content comprising 46.2%. Genome contained 23 contigs encoded by 3881 protein-coding genes with nine rRNA and 53 tRNA genes. A comparative study demonstrated that strain GZB bloomed with some potential features as compared to other *Bacillus* species. In addition, strain GZB developed spore cells and displayed laccase activity while growing at elevated stress levels. Most importantly, strain GZB contained many protein-coding genes associated with BPA degradation, as well as the degradation of several other compounds. The protein-coding genes in the genome revealed the genetic mechanisms associated with the BPA degradation by strain GZB. This study predicts four possible degradation pathways for BPA, contributing to the possible use of strain GZB to remediate different polluted environments in the future.

**Keywords** Bisphenol A · Bioremediation · *Bacillus* sp. GZB · Electronic-waste · Genome

## Introduction

Bisphenol A [BPA; 2, 2-bis (4-hydroxyphenyl) propane] is a synthetic organic compound, produced at high volumes worldwide (Huang et al. 2012; Im et al. 2016). BPA is an essential constituent in the manufacturing of polycarbonate plastics, epoxy resins, and other applied materials; these materials are found in many every day products, such as baby bottles, food containers, thermal papers, lacquers, water pipes, toys, medical equipment, and electronics (Rochester et al. 2015; Larsson et al. 2017). Broad applications and human activities have made BPA ubiquitous in water, sediment/soil, the atmosphere, and in living flora and fauna worldwide (Grignard et al. 2012; Li et al. 2012; Chen et al. 2016). BPA is an endocrine disruptor, genotoxic, neurotoxin, and estrogenic compounds that poses significant risk to all living organisms, including human health (Grignard et al. 2012; Rochester et al. 2015; Wu et al. 2017). This makes it important to protect the environment and human beings from the impact of BPA by developing an efficient remediation system. Implementing indigenous microbes to

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# Bisphenol AF exerts estrogenic activity in MCF-7 cells through activation of Erk and PI3K/Akt signals via GPER signaling pathway

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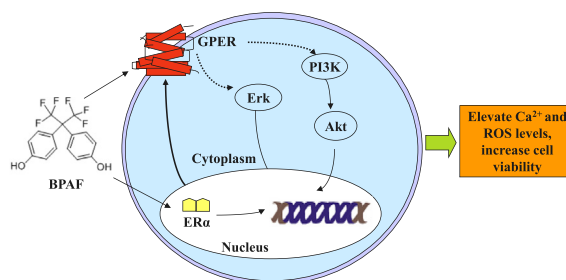
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## HIGHLIGHTS

- BPAF promotes cell proliferation, and elevates ROS and  $\text{Ca}^{2+}$  levels in MCF-7 cells.
- BPAF activates PI3K/Akt and Erk signaling pathways via GPER.
- Activation of GPER mediated signals stimulates BPAF induced cell biological effects.
- ER $\alpha$  plays a key role in cell biological effects induced by BPAF.
- BPAF can exert estrogenicity by interactions between ER $\alpha$  and GPER mediated signals.

## GRAPHICAL ABSTRACT



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## ABSTRACT

The negative health effects of bisphenol A (BPA) due to its estrogenic activity result in the increasing usage of alternative bisphenols (BPs) including bisphenol AF (BPAF). To comprehensive understand health effects of BPAF, the MCF-7 cells were used to investigate the effects of BPAF on cell proliferation, intracellular reactive oxygen species (ROS) formation, and calcium ion ( $\text{Ca}^{2+}$ ) level. The molecular mechanisms of cell biological responses caused by BPAF were investigated by analyzing target protein expression. The results showed that low-concentration BPAF induces significant effects on MCF-7 cells, including promoting cell proliferation and elevating intracellular ROS and  $\text{Ca}^{2+}$  levels. BPAF in low concentration significantly enhances the protein expression of estrogen receptor  $\alpha$  (ER $\alpha$ ), G protein-coupled receptor (GPER), c-Myc, and Cyclin D1, as well as increases phosphorylation levels of protein

**Abbreviations:** BPA, bisphenol A; BPAF, bisphenol AF; CCK-8, cell counting kit-8; DCFH-DA, 2',7'-Dichlorodihydrofluorescein diacetate; DMSO, dimethyl sulfoxide; ER, estrogen receptor; Erk, extracellular signal-regulated kinase; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; GPER, G protein-coupled receptor; ICI, ICI182780; MK, MK-2206 2HCl; PI3K/Akt, phosphoinositide 3-kinase/protein kinase B; ROS, reactive oxygen species; SD, standard deviation; SDS-PAGE, sodium dodecyl sulfate-polyacrylamide gel electrophoresis; siGPER, siRNA targeting GPER; siNC, siRNA vector; siRNA, small interfering RNA; *t*-BHP, *tert*-butyl hydroperoxide; Wor, wortmannin.

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