Environmental Research 180 (2020) 108897

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

# The decomposition and ecological risk of DDTs and HCHs in the soil-water system of the Meijiang River

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ARTICLE INFO

*Keywords:*
Organochlorine
Sediments
Meijiang river basin
Soil-water system

ABSTRACT

This research project was designed to study the residues of OCPs (organochlorine pesticides) in the sediments of the Meijiang River Basin. Samples from the Meijiang River Basin were analyzed by gas chromatography-mass spectrometry after being pretreated by Soxhlet extraction, and their compositions, distributions and sources were evaluated. The current study presents the distribution of OCPs in the soils and sediments of the Meijiang River Basin. The results demonstrate that OCPs contamination is an important environmental concern due to the excessive use of these compounds in the agricultural and industrial sectors. The ratios of α-HCH/γ-HCH, (DDE + DDD)/ΣDDTs, p,p-DDT/o,p-DDT, and DDD/DDE were used as indices for identifying the possible pollution sources and assessing the decomposition of the parent compounds and the recent γ-HCH and DDT inputs. At the XY (Xiyang) and DSGYY (Dongshenggongyeyan) sites, the pollutants had industrial origins. At other sites (QTH (Qutianhu), LXC (Longxichun), ZJC (Zhenjiaochun), HKC (Hekouchun), GS (Guangshan) and RGQ (Raogongqiao)), the pollution was caused by dissolved organic matter. The SHB site was polluted by transportation and upstream pollutants. At the SXC (Shixichun), YZX (Youzhihe), DSH (Dongshihe) and ZGG (Zhegupai) sites, the metabolite was p,p'-DDD and was produced in an environment with anaerobic conditions. At the FJC (Fujiangkou), QTH (Qiutianhu), GS (Guangshang) and MX (Meixi) sites, the metabolite was DDE and was produced under aerobic conditions. In view of the health risks, the risk quotients for these contaminants were evaluated, and all risk quotients were less than 1 under the best-case scenario. This result suggests that the investigated pollutants may pose little hazard to the local ecosystem. The sediments containing toxic pesticides had a less than 55% ecological risk, indicating that the ecological risk of HCHs in the soils from the Meijiang River Basin is low.

## 1. Introduction

Large quantities of pollutants have been discharged into the rivers in China, and sources of fresh water are under immense stress caused by the rapid development of industry, agriculture, and urbanization and the unsustainable use of pesticides in China. Organochlorine pesticides (OCPs) are of concern because of their persistence in the environment, their toxicity, and their tendency to bioaccumulate in animals, including humans, via food chains (Chen and Chen, 2008; Thomas and Toms, 2017). These compounds have been found in different environmental media, such as water, air, soil and sediment, and in various organisms, including humans (Mishra and Sharma, 2012; Thomas and Toms, 2017). More than 300 million people rely on hazardous drinking water sources that are contaminated with untreated sewage, industrial pollutants and agricultural chemicals (Lin and Nizzetto, 2016). However, organic chemicals of concern with respect to ecological and human health are underemphasized in the water quality assessment criteria (Sánchezosorio and Macíaszamora, 2017). Due to their low water solubilities and high octanol-water partition coefficients (KOW), OCPs tend to accumulate in sediments (Placencia and Contreras, 2018). When sediments, an important source and sink for OCPs, are resuspended, they can release bound OCPs from particles into the water under certain conditions, which can result in the secondary contamination of water (Bchir, 1988; Lin and Nizzetto, 2016; Shoiful and

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https://doi.org/10.1016/j.envres.2019.108897
Received 6 August 2019; Received in revised form 28 October 2019; Accepted 4 November 2019
Available online 07 November 2019
0013-9351/ 

Ueda, 2016).

OCPs (HCH, DDT) are introduced into the aquatic environment through the discharge of domestic sewage and industrial wastewater, runoff from nonpoint sources, agriculture inputs, wet or dry deposition, and other means (Mishra and Sharma, 2012; Yun and Yang, 2014; Yohannes and Ikenaka, 2016; Choi and Kim, 2018). The transfer of OCPs from sediments to organisms through the interactions between water and sediment has been considered a major route of exposure for many aquatic plants and animals, including waterbirds (Yohannes and Ikenaka, 2016; Wang and Bai, 2017; Placencia and Contreras, 2018). In China, the presence of OCPs in the sediments of rivers, reservoirs, and lakes has been extensively studied (Zhu and Liu, 2005; He and Qin, 2012; Lin and Nizzetto, 2016; Wang and Bai, 2017; Zhang and Xia, 2017).

Despite continuously increasing pollution in recent decades, there is little information on environmental contamination in the Meijiang River Basin. The aim of this work was to determine the current status of OCPs residues in the surface sediments of the Meijiang River Basin and to assess the associated ecological risk. As this basin is the major source of water resources in the area, the management of OCPs is particularly important for the sustainable development of the basin. Based on the observed changes in OCPs in the basin, we consider in this paper the reasons for these changes and how OCPs might change in the future. Furthermore, their compositions, possible sources, and temporal variations are discussed to inform future strategic environmental management efforts.

## 2. Materials and methods

### 2.1. Reagents

Individual OCPs (1000 mg/L) were purchased from the National Standard Material Center (Beijing, People's Republic of China). Standard mixtures of the various compounds were prepared in methanol at the desired concentrations. Eight isomers were analyzed in the samples: α-HCH, β-HCH, γ-HCH, δ-HCH, ε-HCH, o,p′-DDE, p,p′-DDE, o,p′-DDD, p,p′-DDD, o,p′-DDT, and p,p′-DDT. Other chemicals were of analytical reagent grade.

### 2.2. Study area

The Meijiang River Basin is the primary residence of the Hakka people. The Meijiang River runs roughly northeast to southwest in the Meijiang River Basin in Meizhou, China. The Meijiang River Basin is within 90 km of Meizhou and has an area of 14,060.9 $km^2$, an average width of 200–250 m, and a riverbed gradient of 0.59 per kilometer. The riverbed is 250–300 m wide, and the river water surface slope is 4‰. Because the river flows through the tertiary sand and shale of the hilly region of the Red Basin and the Jurassic coal measure strata, the vegetation is sparse, water loss and soil erosion are severe, and the deposition of riverbed sediment is wide and shallow. During the wet season, the river cannot typically be crossed with a vehicle. The normal water level is 3–5 m below the bank, and the river cannot be used for gravity irrigation.

### 2.3. Sample collection

Sediment samples were collected using a soil sampler column with a hydraulic booster that was inserted vertically during a low water period in the waterfront area of the riverbed. Three parallel samples were collected at each sample site. Three samples were collected from each vertical parallel sample collected (from 0 to 3, 7–10, and 12–15 cm; each sample was approximately 3 cm thick), a total of 84 samples. The samples were collected in polyethylene bags and then labeled and stored at −70 °C in the laboratory. The sediment samples were subsequently thawed and air-dried, and impurities were removed via trituration using 60-mesh metal screens ($r < 0.28$ mm); the resulting samples were redried and set aside.

### 2.4. Sample extraction and purification

#### 2.4.1. Soxhlet extraction

From each of the screen-processed samples, a 10 g sediment sample was weighed and placed in a 50 ml beaker with 1 ml distilled water and 2 g of diatomite, and the contents were mixed thoroughly. The mixture was transferred to an extraction tube, which was then placed into a 250 ml Soxhlet extractor. A petroleum ether/acetone mixture (100 ml, 1:l) was added to the Soxhlet extractor, and the samples were soaked for 12 h. The Soxhlet extractor was then placed in a constant-temperature water bath, and the samples were extracted for 4 h at 75–95 °C. After being cooled, each extract was transferred to a 500 ml separatory funnel, and the extractor and the flask were washed three times with 10 ml petroleum ether. The wash was added to the separatory funnel, and 100 ml of a sodium sulfate solution (1.96%) was added. The mixture was shaken well for l min and then allowed to stand and separate; the lower aqueous layer was discarded, and the upper petroleum ether layer was retained for purification.

#### 2.4.2. Purification

The sulfonation method was used for purification. Ten milliliters of concentrated sulfuric acid (18.4 mol/L) was added to the separatory funnel. The mixture was shaken well for l min by hand and then allowed to stand and separate, and the lower sulfate layer was discarded. This procedure was repeated 5 times until the petroleum ether extract in the two-phase interface was clear and colorless. Next, 20 ml of a sodium sulfate solution was added to the petroleum ether extract, the mixture was shaken well for l min and then allowed to stand and separate, and the lower aqueous layer was then discarded; this was repeated until only the extract layer remained. The extracted mixture was then dried over a small amount of anhydrous sodium sulfate dihydrate in double ball tube. Finally, the extracted mixture was filtered into a 250 ml flat-bottomed flask for enrichment.

#### 2.4.3. Concentration determination

Using an RE-52B rotary evaporator (temperature-controlled at 40 °C), the extracted mixture was enriched to 5 ml and then further enriched to 2 ml under nitrogen. The samples were stored in a bottle at a constant volume of 2 ml for gas chromatography.

#### 2.4.4. Gas chromatography

Gas chromatography has been widely used as an important tool for the analysis of OCPs in the environment. OCPs were analyzed by a gas chromatograph-mass spectrometer (GC-MS) (Hewlett-Packard 5890 Series II gas chromatograph system, Hewlett-Packard, Ltd., USA) equipped with an on-column injector and an electron capture detector. A one microliter aliquot of the sample extract was automatically injected into an HP-5 capillary column (30 m × 0.25 mm id) (Hewlett-Packard, Ltd.). Ultrahigh purity nitrogen was used as the carrier gas at a speed of 1.0 ml $min^{-1}$. The oven temperature was programmed as follows: maintain 80 °C for 1 min, then increase at 20 °C $min^{-1}$ to 150 °C and then at 5 °C $min^{-1}$ to 300 °C, and then hold at the final temperature for 5 min. The detector was operated at 280 °C. The data were acquired and processed with Chemstation software (Hewlett-Packard).

### 2.5. Quality assurance and quality control

All data were subject to strict quality control procedures. The instruments were calibrated daily with calibration standards. The limits of detection (LODs) of the OCPs were defined as three times the corresponding signal-to-noise ratio (S/N) values. A solvent blank and matrix blank were processed throughout the entire procedure and analyzed prior to and after every 10 samples. Each sample was analyzed

**Table 1**
Concentrations of organochlorine pesticides in the sediment of Meijiang River unit: μg/kg.

| statistical magnitude | average value | median | standard deviation | CV | MAX | MIN |
|---|---|---|---|---|---|---|
| α-HCH | 1 | 0.57 | 1.25 | 125.33 | 0.06 | 5.53 |
| β-HCH | 3.94 | 3.84 | 2.77 | 69.55 | 0.19 | 9.98 |
| γ-HCH | 2.74 | 2.32 | 1.85 | 67.36 | 0.54 | 8 |
| δ-HCH | 0.56 | 0.51 | 0.38 | 69.3 | 0.04 | 2.01 |
| ΣHCHs | 8.24 | 8.85 | 4.44 | 53.92 | 1.63 | 20.88 |
| p,p'-DDE | 0.75 | 0.53 | 0.56 | 74.64 | 0.27 | 3.32 |
| p,p'-DDD | 0.8 | 0.71 | 0.39 | 49.06 | 0.37 | 2.24 |
| o,p'-DDT | 3.35 | 3.5 | 0.63 | 18.66 | 1.58 | 4.38 |
| p,p'-DDT | 5.5 | 5.65 | 0.72 | 13.13 | 3.65 | 7.17 |
| ΣDDTs | 10.4 | 10.48 | 1.36 | 13.1 | 7.15 | 13.29 |
| HCB | 1.87 | 1.88 | 1.18 | 62.9 | 0.09 | 5.37 |
| Heptachlor | 1.18 | 1.13 | 0.48 | 40.92 | 0.46 | 2.7 |

in triplicate unless otherwise stated. The average recoveries of the surrogate standard TCmX were 72 ± 8%. The recoveries of the OCPs ranged from 72 to 110%. The LODs of individual OCPs ranged from 0.15 to 0.30 ng/L. The reported OCPs concentrations were corrected according to the recoveries of the standards.

## 3. Results

### 3.1. Quantitative analysis of the soil weathering process

The total OCPs concentration of the sediment samples was 11.81–39.20 μg/kg, and the mean concentration was 21.68 μg/kg. Among the OCPs, DDTs had the highest concentrations (10.40 μg/kg) and were present primarily as the p,p'-DDT isomer. The concentration of HCHs was 8.24 μg/kg, and HCHs were present primarily as the γ-HCH isomer. In contrast, the concentrations of HCB and heptachlor were comparatively low at 1.87 μg/kg and 1.18 μg/kg, respectively. The total OCPs concentration in the sediments was higher than that in the soils, and the mean OCPs concentration in sediment was 18.6 μg/kg. The concentrations of DDTs and HCHs were 11.93 μg/kg and 4.01 μg/kg, respectively (shown in Table 1). Compared with the sediment core of the Xinfengjiang Reservoir in Heyuan City Guangdong Province, the concentration of HCHs and DDTs in Core XFJ-1 ranges from 0.26 to 3.90μg/kg and from 1.00 to 3.96 μg/kg, respectively(LIN and LI, 2010). The sediment concentration of Meijiang river was higher than that of Xinfengjiang Reservoir in heyuan. Vertical distribution characteristics of HCHs and DDTs show these compounds were come from the secondary source that was transported by runoff from agricultural waste water and soil erosion in Meijiang basin. As shown, γ-HCH was the most abundant of the studied HCH isomers (with a mean value of 79.43%), with lower percentages of α-HCH (7.06%) and β-HCH (13.51%); the overall trend was γ-HCH > β-HCH > α-HCH > δ-HCH. In Pingyuan County, there was a high level of β-HCH in the soil of the Dongshi River. Of the 4 isomers, α-HCH had the lowest residue levels, and γ-HCH had the highest. High concentrations of DDTs were observed in the upper and middle reaches of the basin. The concentrations of HCHs were 1.63–20.88 μg/kg (average values), and the rank order of OCPs was p,p'-DDT > γ-HCH > o,p'-DDT > β-HCH > α-HCH > p,p'-DDT > p,p'-DDE > δ-HCH. Relative to the concentrations of OCP residues in sediments reported nationally and internationally, the total OCP concentration of the Meijiang River Basin represented a moderate level of overall pollution. According to 0–5, 15–20 cm sediment sample, vertical profile of α-HCH, γ-HCH, o,p'-DDT and p,p'-DDT indicate that the compounds still have new input by the discharge of sewage from the near newly built industrial park.

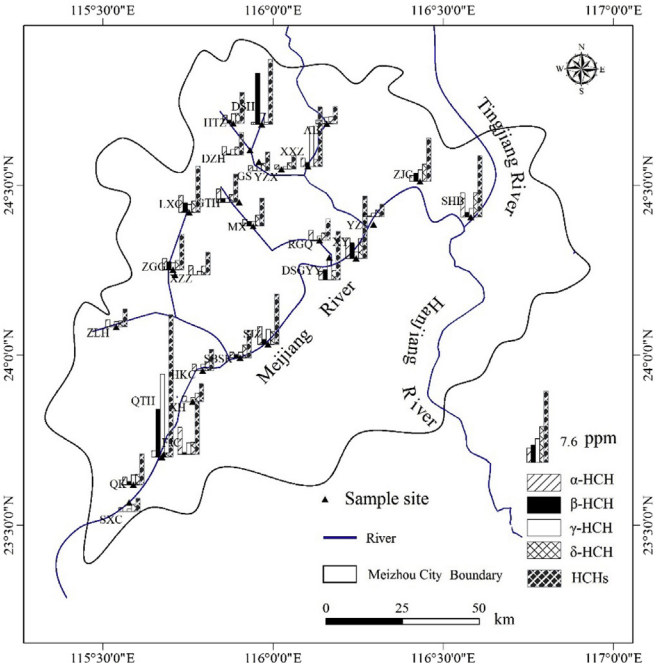


**Fig. 1.** Distribution of HCHs isomers in the soils from Meijiang River.

### 3.2. Distributions of HCH and DDT isomers

The results were analyzed using ArcGIS 13.0 for spatial distribution simulations. The spatial distribution simulation of HCH in soil samples from the Meijiang River Basin is shown in Fig. 1. A possible explanation for this result is that β-HCH exhibits slower degradation than the other isomers due to its high symmetry and great chemical stability. In addition, γ-HCH is readily soluble in water, and it can be easily degraded to α-HCH, the concentration of which was significantly higher in the soil of Qiutian Lake in Wuhua County than in the soils of the other sites.

The spatial simulation of the soil sample DDT test results is shown in Fig. 3. Technical-grade DDT contains p,p'-DDT (75%), o,p'-DDT (15%), p,p'-DDE (5%), and other isomers (< 5%). At the LXC (Longxichun) and DSGYY (Dongsheng gongyeyan) sites, the concentration of o,p'-DDT was greater than the concentration of p,p'-DDT. DDT isomers are persistent in the environment, and their concentrations in this study are shown in Fig. 2. The general trend was p,p'-DDT > o,p'-DDT > p,p'-DDE > p,p'-DDE. The p,p'-DDT isomer was higher in the soil of Longxichun Village and the DSGYY industrial park than in the soils of the other sampling points.

The detection rate for all 8 OCPs except β-HCH was 100% (Fig. 3). There was substantial variation in the distributions of OCPs residues; HCHs were high in the sediments of the middle and lower reaches of the Meijiang River Basin. High concentrations of HCB and heptachlor were observed in the lower reaches of the Meijiang River Basin. The analysis showed that the OCPs concentrations reflected not only existing residues in the sediment but also fresh inputs of HCHs and DDTs from locations such as the Dongsheng Industrial Park and the Shejiang Industrial Park, which may reflect the development of industry along the river in recent years.

The sources of HCH and DDT contamination were early stage residues in the environment and more recent inputs of HCHs and DDTs. The total HCH concentration had a slight U-shaped distribution along an east-west orientation; from south to north, it exhibited a linear increase, but the range of concentrations was minimal. The p,p'-DDE isomer showed a slight U-shaped distribution from both east to west and north to south. The o,p'-DDT isomer had a parabolic distribution from both east to west and north to south. For p,p'-DD, p,p'-DDT and ΣDDTs, there was a tendency for concentrations to decrease from west

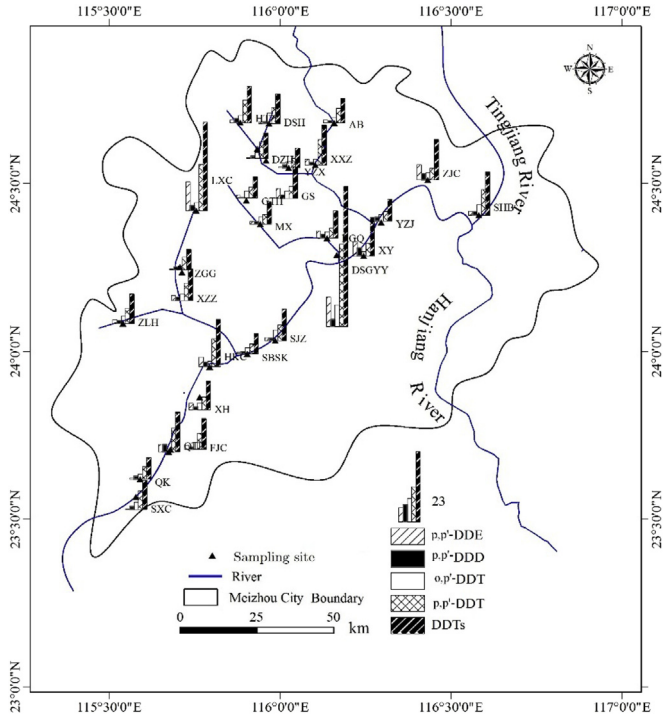


**Fig. 2.** Distribution of DDTs isomers in the soils from Meijiang River.

to east, whereas from north to south, the concentrations linearly increased.

### 3.3. Degradation of HCH and DDT isomers

It has been documented that approximately 55–70% of HCH is α-HCH, 5–14% is β-HCH, 10–18% is γ-HCH, and 6–10% is δ-HCH and other isomer and that HCH can produce a purified c-isomer of lindane. These HCH isomers have different physical and chemical properties. The α-HCH and γ-HCH isomers can be readily separated from the sediment because of their values of Henry's law constant. β-HCH has low water solubility and vapor pressure; it is, therefore, the most stable HCH isomer and is more resistant than the other isomers to microbial degradation.

There was no recent input of technical HCH detected at the DSH (Dongshihe), QTH (Qiutianhe) and LXC (Longxichun) sites; in the sediments, the concentration of β-HCH was much greater than the concentrations of the other HCH isomers (δ-HCH, α-HCH and γ-HCH). Typically, α-HCH and γ-HCH are converted to β-HCH in the environment. Therefore, β-HCH predominates in the sediments if there is no fresh input of technical HCH. Vertical distribution characteristics of HCHs show these compounds were come from agricultural waste water. In contrast, the predominance of γ-HCH in the sediment reflected the recent use of lindane, as was observed at the XY (Xiyang), DSGYY (Dongsheng gongyeyan) and SHB (Sanheba) sites. The predominance of γ-HCH in some environmental samples reflects the recent use of lindane. The XY (Xiyang), DSGYY (Dongsheng gongyeyan) sites are emerging industrial parks, and SHB (Shanheba) is at the junction of the Meijiang River and the Tingjiang River, which experiences a large amount of water transportation and acts an accumulation point for upstream pollutants.

In the present study, most ratios of α-HCH/γ-HCH were far below 3 and varied from 0.08 to 2.44 (Fig. 4). These results indicated that most of the α-HCH in the middle and lower reaches of the Meijiang River was degraded. Furthermore, it was found that new γ-HCH had been input at XY (Xiyang), SHB (Shanheba) and GTH (Guangtian). The ratio of α-HCH to γ-HCH has been used to identify the possible sources of HCH. A ratio of α-HCH/γ-HCH less than 3 suggests that the surrounding environment has replaced the industrial HCHs in the water and the sediment. Vertical profile of α-HCH, γ-HCH indicate that the compounds still have new input by the discharge of sewage from the near newly built industrial park. These pollutants mainly come from surfactant metabolism. These pollutants mainly come from surfactant metabolism. The low α-HCH/γ-HCH ratio in the sediment implied the usage of lindane. A ratio between 3 and 7 suggests the HCH may have been transported over long distances in the atmosphere from the fresh input of technical HCH from industrial sources (such as from GTH (Guangtianhe), XY (Xiyan), and SHB (Shanheba) in the basin). Because of structural differences between γ-HCH and α-HCH, the isomer γ-HCH decomposes in the environment more rapidly than α-HCH. Therefore, after industrial HCHs enter the environment, if there is no new industrial HCH input, the existing γ-HCH will eventually be converted into α-HCH. Therefore, it can be concluded that lindane may have been used recently in the Meijiang River Basin. In the absence of recent use, the ratio of α-HCH/γ-HCH would be expected to be less than 3 in most of the basin.

In the present study, most of the sample sites were found to have had new DDT input in the Meijiang River Basin. DDT can be biodegraded to DDE under aerobic conditions and to DDD under anaerobic conditions. The ratio (DDE + DDD)/DDTs characterizes the degree of degradation of the pesticide DDT; in the present study, it was used to determine whether new input of DDT had occurred. The decomposition

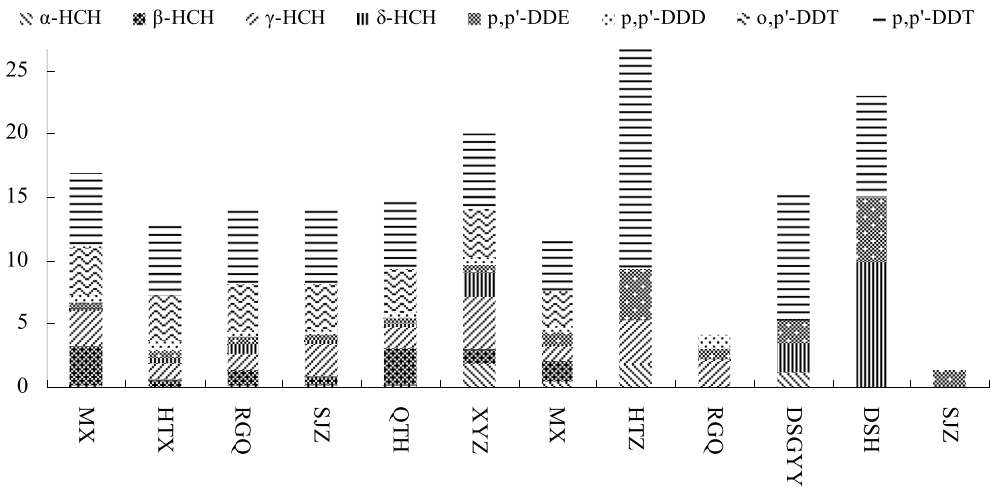


**Fig. 3.** Total of HCHs and DDTs isomers in the sediments from Meijiang River.

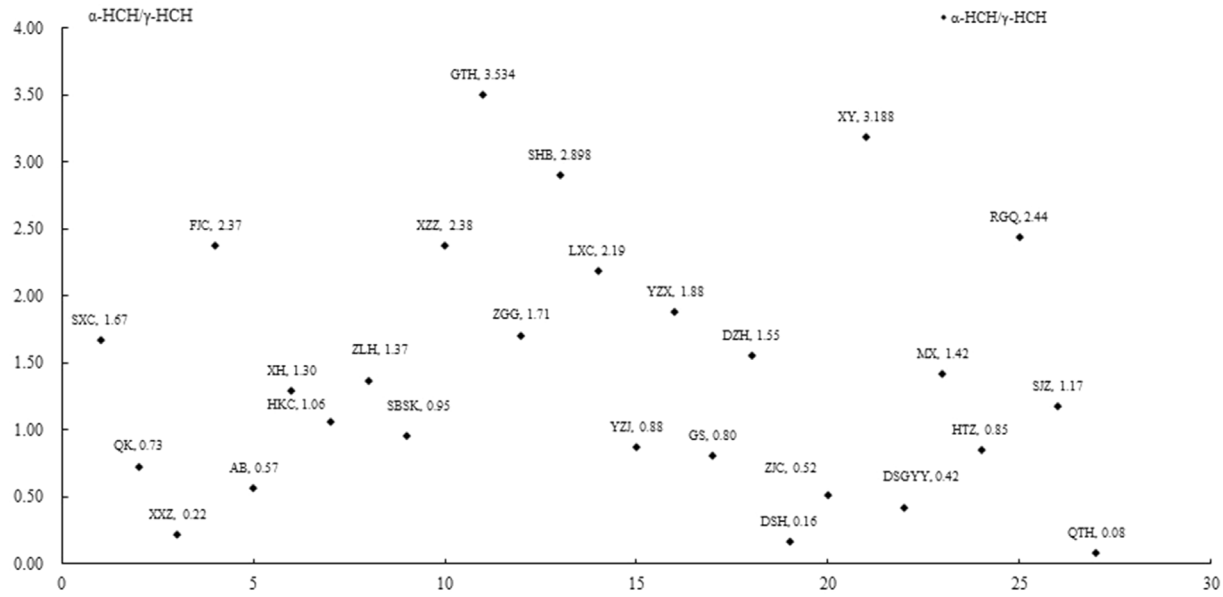


**Fig. 4.** Ratio of α-HCH/γ-HCH in soils of Meijiang River.

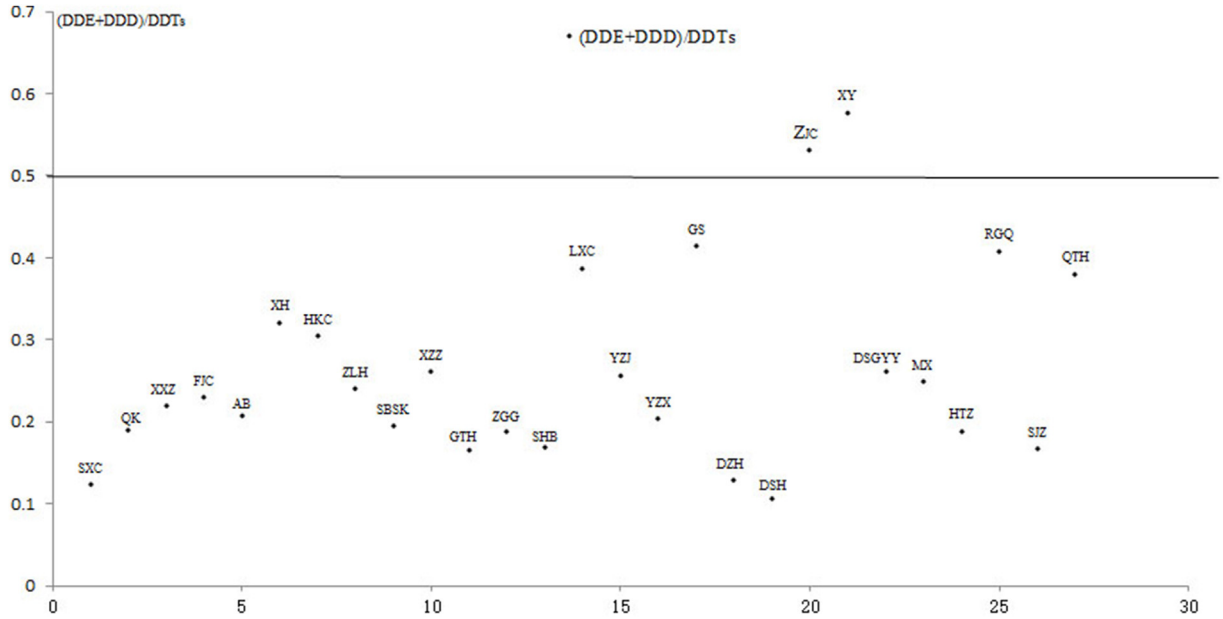


**Fig. 5.** Ratio of (DDE + DDD)/DDTs in soils of Meijiang River.

of the parent compound and the recent DDT input were used to assess the possible sources of the pollution (i.e., DDE + DDD)/ΣDDTs, p,p-DDT/o,p-DDT, and DDD/DDE). The relative concentrations of the parent DDT compound and its biological metabolites were used to assess the decomposition of the parent compound because of DDD and DDE weathering process. When the ratio (DDE + DDD)/ΣDDTs is > 0.5, the DDT can be assumed to have been subjected to a long-term weathering process, with no new DDT inputs; ratios > 0.5 were observed at sites XY (Xiyang) and ZJC (Zhuozhaichun) (Fig. 5). In contrast, a ratio (DDD + DDE)/DDTs < 0.5 indicates new DDT input; ratios < 0.5 were observed for most of the sample sites in the basin.

A ratio of DDD/DDE greater than 1 indicates that the sediment is dominated by DDD, which is the product of anaerobic degradation of DDT; a ratio of less than 1 indicates that the sediment is dominated by DDE, which is the product of aerobic degradation of DDT (Ahmed et al., 2016). Therefore, the ratio of DDD/DDE can be used to characterize the degradation of DDT in the environment. When p,p'-DDD/p,p'-DDE > 1, it indicates that the dominant metabolite is p,p'-DDD and that the metabolic environment was anaerobic, as was observed at the sites SXC (Shixichun), YZH (Youzhihe), DSH (Dongshihe) and ZGG (Zhegupai). When p,p'-DDD/p,p' –DDE < 1, it indicates that the dominant metabolite is DDE and that the metabolic environment was aerobic, as was observed at the sites FJC (Fujiangkou), QTH (Qiutianhe), GS (Guangshang) and MX (Meixi) (Fig. 6).

In the present study, the concentration of p,p'-DDT was higher than the concentration of o,p'-DDT at QTH (Qutianhu), LXC (Longxichun), XY (Xiyang), ZJC (Zhenjiaochun), HKC (Hekouchun), DSGYY (Dongshenggongyeyan), GS (Guangshan) and RGQ (Raogongqiao), as shown in Fig. 7. The biodegradable DDT was metabolized into different isomers in the different natural environments. Had there been no new DDT input, the relative concentration of DDT would have been decreased, and the content of the corresponding product would have been increased. The sites XY (Xiyang) and DSGYY (Dongsheng gongyeyan) may be receiving industrial inputs. At other sites QTH (Qutianhu), LXC

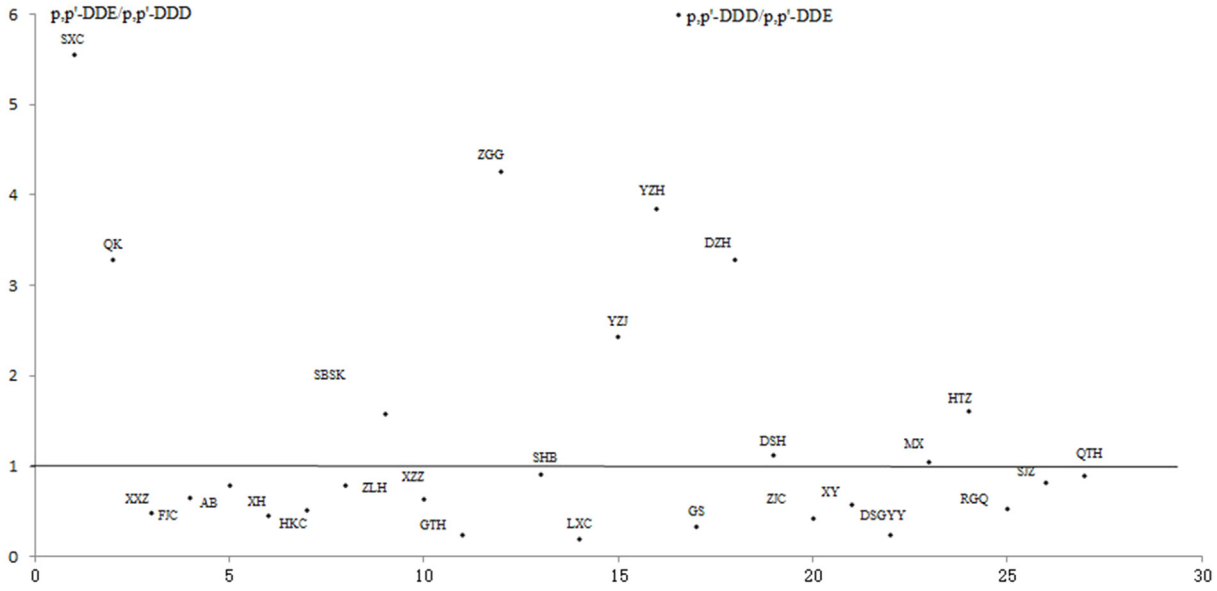


**Fig. 6.** Ratio of DDT/DDE in soils of Meijiang River.

(Longxichun), XY (Xiyang), ZJC (Zhenjiaochun), HKC (Hekouchun), there may have been a high organic matter content in the water; alternatively, the dissolved oxygen content in the water may have been low. Generally, o,p'-DDT degrades more readily than p,p'-DDT. After DDT was banned, the production of DDT primarily occurred as an intermediate in dicofol production (Qu and Sun, 2018). In the present study, the detection of more op'-DDT than p,p'-DDT in the environment suggests an input of DDT at most sample sites.

### 3.4. Assessment of potential ecological risk

The levels of HCHs and DDTs in the water and sediment were low, and the concentrations of HCHs and DDTs in fish were lower than those in other aquatic animals in the Meijiang River Basin. However, the input of liquid industrial waste, which is the source of organochlorines, into the basin has not stopped, so potential ecological risk remains. Historically, lindane or technical HCH was probably the source of the HCHs in the basin, whereas technical DDT might be the source of the DDT (Zhang and Xia, 2017). The ecological risk was evaluated using the standard risk assessment of Ingersoll Rand. Some ecological risk was detected for the upper and middle reaches of the Meijiang River Basin, indicating that OCPs in the sediments of the region may cause harm to the ecological environment. The ecological risk from the HCHs in the soils from the Meijiang River Basin is low. Compared with other regions in Guangdong, Huizhou city was lower in soi1 HCH and DDT content Principal component analysis demonstrated that 17 OCPs in the soil may have 5 major contributors corresponding respectively to industrial use of HCH, natural factory use of lindane use of heptamul and use of Drinox(Ma and Zhou, 2008; Huang and Peng, 2010; Ma and Qiu, 2010). The source and distribution of HCH and DDT wes very similar in these three cities. The highest concentrations of HCHs and DDTs were observed for the sediment and soil samples from the upper and middle reaches of the Meijiang River Basin; these reaches have been actively used for fisheries and are surrounded by suburban rural areas and farmlands. DNA methylation analysis has indicated that high plasma OCPs levels are associated with increased biological age (Ju and

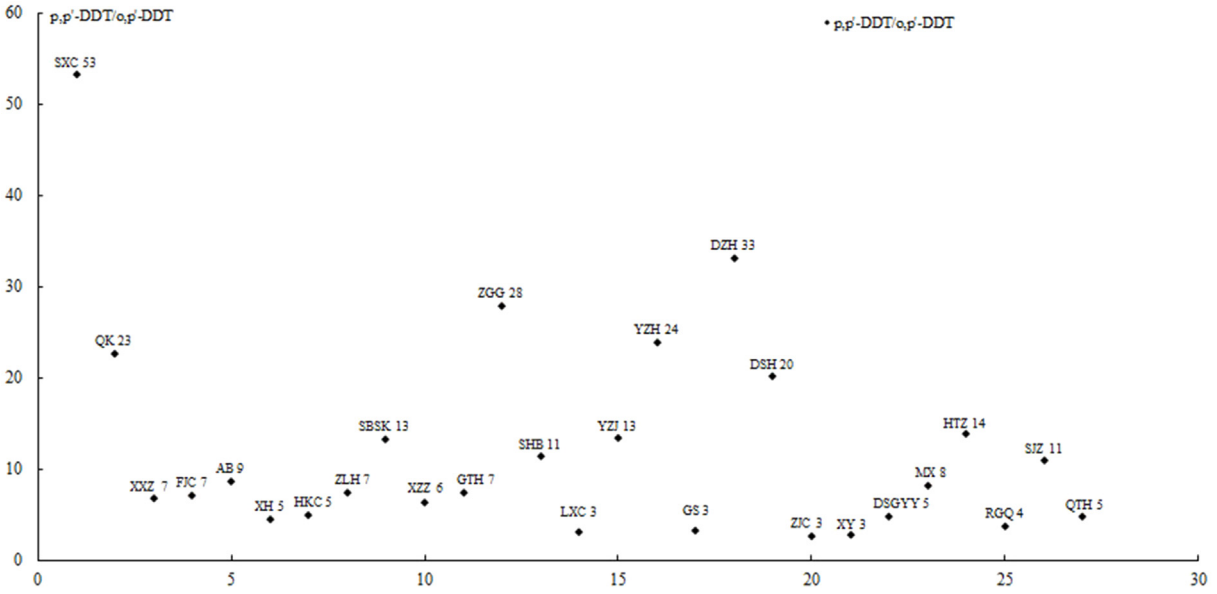


**Fig. 7.** Ratio of p,p'-DDT/op'- DDT in soils of Meijiang River.

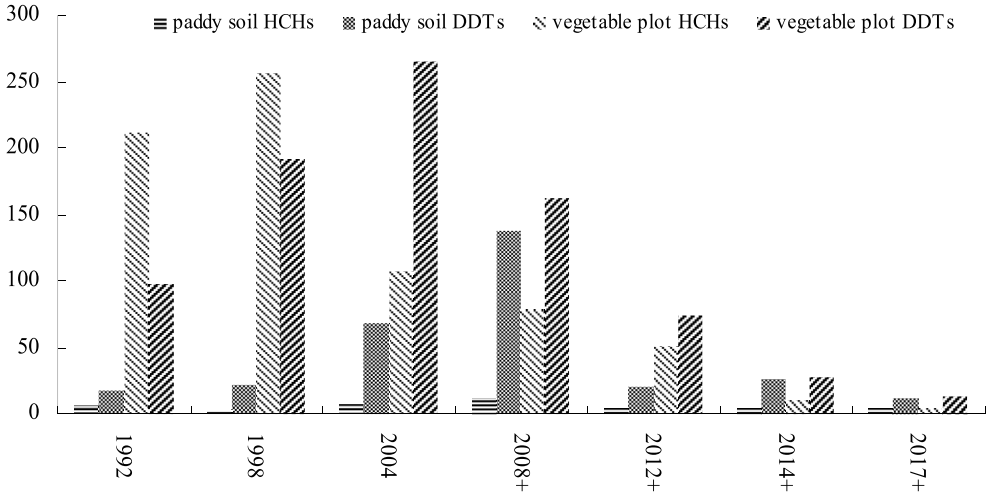


**Fig. 8.** The Decomposition of DDTs in different Soils by potting.

GanXiao, 2009; Lind and Salihovic, 2018). Evaluation of the main tributary of the Meijiang River showed that although the Meijiang River Basin River is in a state of "basic health", as indicated by its overall health index of 0.611, the index of social services, which was less than 6 points, was inadequate. This poor social services index score was obtained because the river pollution reduced the water quality and created navigational obstructions.

### 3.5. The decomposition of DDTs in soils

The degradation of DDT in nature can be accomplished through photochemical degradation, physical processes and natural biological functions. The decomposition of DDT in soils is primarily dependent on biological degradation by microorganisms. *Alcaligenes*, *Sphingomonas* and *Pseudomonas* bacteria are the primary strains responsible for the degradation of DDTs. These strains all possess degradation properties. Low concentrations of DDTs may promote the catabolism of amine/amino compounds by soil microbes, whereas high concentrations of DDTs my inhibit it; in a 15-year experiment, high DDT concentrations strongly inhibited the degradation of amine/amino compounds by microorganisms in soil (Fig. 8). Under high concentrations of DDTs, the microbes that persist in the soil are typically able to degrade DDT or are resistant to DDT (e.g., *Brevundimonas* sp.); populations of gram-positive bacteria in the soil of rice and vegetable crops rapidly decrease in the presence of HCHs and DDTs.

## 4. Conclusions

The total OCPs concentration in sediments was higher than that in soils, with a mean sediment concentration of 18.65 μg/kg. The concentrations of DDTs and HCHs were 11.93 μg/kg and 4.01 μg/kg, respectively. There was a high level of β-HCH in the soil of the Dongshi River, and there was a significant quantity of α-HCH in the soil of Qiutian Lake in Wuhua County. The p,p'-DDT concentrations were elevated in the soil of Longxi Village and the DSGYY industrial park relative to those at the other sampling points.

In the present study, most of the α-HCH in the middle and lower reaches of the Meijiang River was degraded. However, there were new γ-HCH inputs detected at the XY (Xiyang), SHB (Shanheba) and GTH (Guangtianhe) sites. A predominance of γ-HCH in the sediment reflects the recent use of lindane; XY (Xiyang) and DSGYY (Dongsheng gongyeyan) are emerging industrial parks, and SHB is at the junction of the Meijiang and Tingjiang Rivers, which experiences a large amount of water transportation and acts an accumulation point for upstream pollutants. At the SXC (Shixichun), YZX (Youzhihe), DSH (Dongshihe) and ZGG (Zhegupai) sites, the primary metabolite was p,p'-DDD, and the metabolic environment was anaerobic. At the FJC (Fujiangkou), QTH (Qiutianhu), GS (Guangshang) and MX (Meixi) sites, the primary metabolite was DDE, and the metabolic environment was aerobic. At XY (Xiyang) and DSGYY (Dongsheng gongyeyan), the source of the pollutants was industrial. At the other sites QTH (Qutianhu), LXC (Longxichun), XY (Xiyang), ZJC (Zhenjiaochun), HKC (Hekouchun), the source may have been a high organic matter content in the water or a low dissolved oxygen content.

*Alcaligenes*, *Sphingomonas* and *Pseudomonas* are the primary bacterial strains responsible for the degradation of DDTs. These strains all possess degradation properties. A low concentration of DDT may promote the catabolism of amine/amino compounds by soil microbes, whereas high concentrations of DDT strongly inhibit the degradation of amine/amino compounds by microorganisms in the soil. The results showed that although the Meijiang River Basin River was in a state of "basic health" as indicated by its overall health index of 0.611, the index of social services, which was less than 6 points, was inadequate.

## Acknowledgments

We are grateful for research grants from the National Natural Science Foundation of China (Grant No. 41672180) , Science & Technology Basic Resources Investigation Program of China (Grant No. 2017FY101303; 2017YFC0505205) ; Key Platforms and Scientific Research Projects in Universities in Guangdong Province of China (Grant No. 2018KTSCX212), Guangdong Rural Science and Technology Commissioner Project (2019066) of China.

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