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Determination of Levels of Organochlorine Pesticides in Plastic Resin Pellets on Selected Beaches in the Greater Accra Region of Ghana

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ABSTRACT

The levels of Organochlorine Pesticides (OCPs) in plastic resin pellets were determined with the objective of assessing the status of OCP pollution in the marine ecosystem of selected beaches in Ghana (namely Art Centre, Sakumono, Osu Castle, Labadi, Korle-Gonno, Independence Square and Tema Mighty beaches). The plastic pellets were subjected to Soxhlet extraction and the extracts analyzed using Gas Chromatograph coupled with electron capture detector. High concentrations of Dichlorodiphenyltrichloroethane compounds (DDTs) were recorded followed by Hexachlorocyclohexane (HCHs), Chlordane compounds (CHLs), Hexachlorobenzene (HCB), Aldrin, Dieldrin, Endrin (DRINs), alpha-endosulphan, beta-endosulphan, endosulphan sulphate (Endosulphans) and Methoxychlor. Analysis of the virgin pellets recorded no organochlorine pesticides present. However, plastic pellets collected from all seven beaches were found to contain OCPs with the highest recorded on the Art Centre beach with a total OCP concentration of 106 ng/g. Plastic pellets collected on the Labadi beach recorded the lowest OCPs with a concentration of 20.2 ng/g. The accumulation of OCP residue on the plastic resin pellets suggests that it can be used as a tool for monitoring marine pollution.

Introduction

Many studies have been done to ascertain the role of air, water and sediments in the transport of persistent organic pollutants (Moore et al. 2005; Essumang et al. 2009; Yatawara et al. 2009; Davodi et al. 2011; Zhou et al. 2011; Adu-Kumi et al. 2012), but few have looked at the role of a relatively new environmental medium called plastics (Carpenter et al. 1972; Mato et al. 2002). Plastics are synthetic organic polymers that have existed for decades. We drink out of them, eat out of them, sit on them, and even drive in them. They are durable, lightweight, cheap, and can be made into virtually anything. It is these useful properties of plastics, which make them so harmful when they end up in the environment (Karapanagioti and Klontza 2007).

Plastic resin pellets are the raw material used for the production of plastic products. They are small granules, usually in a shape of a cylinder or a disk and have sizes ranging between 1 and 5 mm in diameter. These plastic pellets can be unintentionally released to the marine environment during manufacturing, transport and directly through accidental spills during shipping. They have been found on beaches all over the world and on the sea floor of the oceans (Mato et al. 2001).

The plastic pellets have been identified as carriers of toxic chemicals in the marine environment due to their persistence and hydrophobic nature. They are either adsorbed from ambient seawater or come from the additives incorporated during the production of the plastic pellets.

Some of these toxic chemicals are persistent organic pollutants (POPs) of which organochlorine pesticides (OCPs) is an example. They are organic substances and are resistant to degradation through normal chemical and biological processes in the environment (Takadaet al. 2006; Karapanagioti and Klontza 2007; Rios et al. 2007).The presence of these OCPs in their immediate environment therefore creates potential hazards that are of great public health concern. In the marine environment, these OCPs may be adsorbed to and carried by plastic pellets, the latter of which may be mistaken for food by marine organisms particularly seabirds, sea turtles, fishes, e.tc. The chemicals may desorb in the digestive tract when taken up by these marine organisms that ingest them. This uptake of chemicals through plastic resin pellets can be a significant pathway for the chemicals to enter marine organisms thereby causing adverse effect (Day et al. 1985; Endo et al. 2005).

The detection of organochlorine pesticide residues in food, water, sediment and air has caused deep concern for both the developed and developing countries with the emergence of its public health effects. In Ghana, many studies have been conducted to determine the residual levels of organochlorine pesticides in different media such as human blood, human milk, fish, lean meat, beef fat, water, sediment and air (Ntow2001, 2005; Darko and Acquaah 2007; Kuranchie-Mensah 2009; Afful et al. 2010; Osei-Tutu et al. 2011; Blankson-Arthur et al. 2011; Adu-Kumi et al. 2012).

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However, there is no data existing for the current state of contamination of plastic resin pellet in the marine ecosystem of Ghana and its associated health implication. In view of this, it was important to assess the organochlorine pesticides in marine plastic resin pellets along the beaches.

Materials and Methods

The Study Areas

The study was carried out in the Greater Accra region of Ghana, focusing on the two major industrialized cities in Ghana, namely Accra and Tema harbour city. The sampling sites (Fig. 1) were Art Centre (N 05° 32' 36.72"; W 00° 11' 41.82") , Independence Square (N 05° 32' 41.79"; W 00° 11' 28.41"), Osu Castle (N 05° 32' 42.18";), Korle-Gonno(N 05° 31' 44.64"; W 00° 13' 31.20"), Labadi (N 05° 33' 44.37" ;W 00° 08' 20.40"), Sakumono (N 05° 36' 39.03"; W 00° 02' 46.47") and Tema Mighty beaches (N 05° 36' 26.85"; W 00° 03' 23.97"). The region is densely populated with a population approximately 3.9 million. These areas are located on coastal zone which represents about 6.5% of the coastal area of Ghana (Ghana Statistical Services 2010).

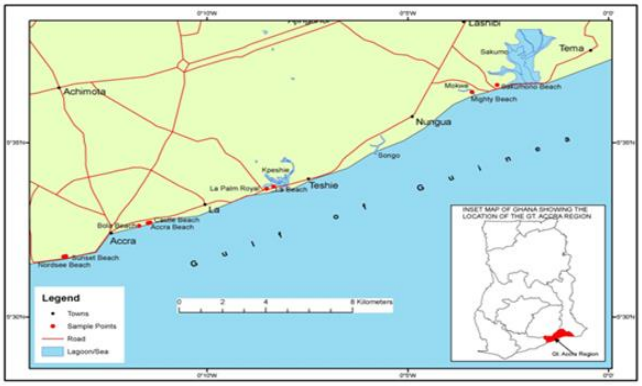

Fig 1. Map of Study area showing the study sites

Sampling.

Samples were collected on the beaches just above the high tide line within a range of 30 metres. The resin pellets were hand-picked from the sand surface into pre-cleaned plastic bags using gloves. Virgin pellets made from polyethylene and polypropylene were obtained from a local plastic company called Ecoplast Plastic Company.

After collection of the pellets from the beach, the pellets were washed with sea water, wrapped with aluminium foil and placed in polyethylene containers with hermitic seals. The samples were then transported to the laboratory at Ghana Atomic Energy Commission, Kwabenya, Accra. At the laboratory, the samples were air-dried under room temperature in a clean room for three days, stored in hermitically-closed polyethylene containers and were kept in a refrigerator at 4º C. The pellets were used in their raw form for all analysis (without crushing or milling). Pictures of the virgin and beached plastic pellets are shown in Fig. 2 and 3.

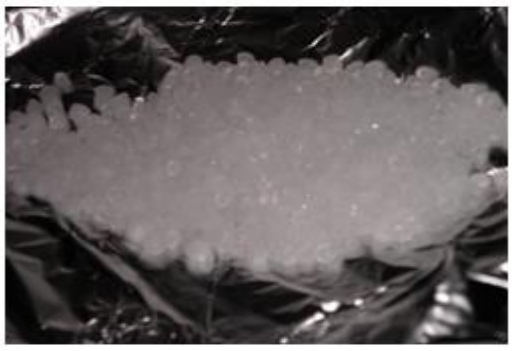

Fig 2. Virgin plastic resin pellets.

Fig 3. Beached plastic resin pellets.

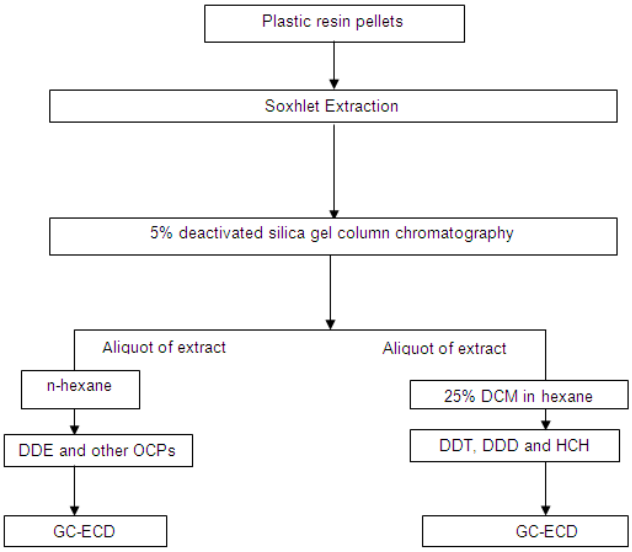

Fig 4. Flow chart of analytical method.

Extraction and Clean-up

Methods of sample extraction and clean-up are described in Mato et al (2001).The whole analytical method and analysis of the plastic pellets has been outlined in Fig. 4

GC analysis

The sample extracts were analyzed by a Varian gas chromatograph CP-3800 equipped with ^{63}Ni electron capture detector of activity 15 mCi with an auto sampler. Exactly 1.0 L of the extracts was injected. Carrier and make up gas was nitrogen at a flow rate of 1.0 and 29 mL/min respectively. The temperature of injector operating in splitless mode was held at 225 ºC, oven temperature was 225 ºC and the Electron Capture Detector was set at 300 ºC respectively.

The column oven temperature was programmed as follows 60 ºC for 2 min 180 ºC/min up to 300 ºC held for 31.80 min. The residues detected by the GC analysis were confirmed by the analysis of the extract on two other columns of different polarities. The first column was coated with ZB-1 (methyl polysiloxane) connected to ECD and the second column was also coated with ZB-17 (58% phenyl, methyl polysiloxane) and ECD was also used as detector.

The pesticide residue was identified based on comparison of the measured relative retention times to those of known standards.

Quality assurance and recovery

The quality of this work was assured through the analysis of standard solution and blank samples included in each batch of samples. In the blank for each extraction procedure, no organochlorine pesticide was detected. One sample of each series was analyzed in three replicates.

Recoveries of organochlorine pesticides were achieved through the analysis of isodrin (OCPs) as internal standards added to each sample. Results of recoveries ranged from 85% to 100%.

Results and Discussion

Organochlorine pesticides detected in plastic pellets

Analysis of plastic resin pellets from the various beaches showed the presence of a number of organochlorine pesticides. The detected compounds were alpha-HCH, beta-HCH, gamma-HCH, delta-HCH (the sum expressed as HCHs), p,p'-DDE, p,p'-DDD, o,p'-DDD, o,p'-DDT, p,p'-DDT (the sum expressed as DDTs), aldrin, dieldrin, endrin (the sum expressed as DRINs), heptachlor, trans-heptachlor epoxy, trans-chlordane, trans-nanochlor (the sum expressed as Chlordane compounds-CHLs), alpha-endosulphan, beta-endosulphan, endosulphan sulphate (the sum also expressed as Endosulphans), hexachlorobenzene and methoxychlor.

Variation of DDTs in plastic pellets

DDT and its related compounds (p,p'-DDT, o,p'-DDT, p,p'-DDE, o,p'-DDE, p,p'-DDD, o,p'-DDD) varied from one location to the other with concentrations ranging from not detected (nd) to 4.38 ng/g. Statistically the difference in the mean concentration of all the DDTs samples were not significant ($p > 0.05$). p,p'-DDE was the most frequently detected DDT metabolite in all sample locations with incidence ratio of 95.24% followed by p,p'-DDT (66.7%), p,p'-DDD (38.10%), o,p'-DDT (19.05%) and o,p'-DDD (9.52%) (Table1).

DDT usually contains 75% of p,p'-DDT, 15% of o,p'-DDT, 5% of p,p'-DDE, and less than 5% of other species

For the measured DDT components, p,p'-DDE (the only DDE recorded) was found to be the highest in concentration when all the individual metabolites were summed from Independence Square, Tema Mighty, Korle-Gonno and Labadi beaches. The total concentrations followed the order p,p'-DDE > p,p'-DDT with the rest having no detection from the said locations (Fig. 5). The p,p'-DDE determined in these four locations had mean values of 2.47 ng/g, 9.72 ng/g, 2.53 ng/g and 2.47 ng/g respectively. These were compared with results of similar work conducted at Seal beach in USA and Rayong beach in Thailand where values of 13.1 ng/g and 23.3 ng/g-pellets were respectively obtained (Table 2). The values of p,p'-DDE from those beaches are however, higher than those of the present study, suggesting less DDT have been used in Ghana than the said countries.

DDT (sum of p,p'-DDT and o,p'-DDT) was the dominant metabolite in the plastic pellet from the Art Centre and Osu Castle beaches (Fig. 5) with mean values of 3.89 ng/g and 2.49 ng/g, respectively. These values are relatively higher when compared with results from Costa Nova beach in Portugal with a value of 1.3 ng/g, but lower than results from the Bay of Maputo in Mozambique also with a value of 7.81 ng/g (Table 2).

With DDD (sum of p,p'-DDD and o,p'-DDD), a value of 1.55 ng/g was recorded in the plastic pellet from the Sakumono beach (Table 1). This was however lower when compared with values from Kato Achaia beach in Greece with a value of 7.81 ng/g and Izmir beach in Turkey with a value of 15.9 ng/g (Table 2).

The high concentration of DDE (metabolite) as compared to DDT (parent) in pellet suggests that DDTs have not been recently used in agriculture after their ban. They are, however, biodegrading from DDT to DDE under aerobic conditions. Higher proportions of p,p'-DDE to p,p'-DDD at the Labadi, Korle-Gonno, Independence Square and Tema Mighty beaches suggest that DDT endured anaerobic transformation in organism. p,p'-DDE has a high chemical stability and hydrophobicity (log Kow value of 6.36) (Guo et al. 2007). DDE present higher values than DDT suggesting that there is no fresh application of the pesticide. DDE has a longer half-life (approximately 7 years) and is however more persistent in the environment than DDT. As a result of this when the input levels of DDT in the environment ceases, the levels of its metabolite DDE will be higher than the levels of parent DDT (Ntow 2005).

Table 1. Mean concentration and range (ng/g-pellet) of DDT, HCH and HCB residue in plastic pellets.

Location of beaches									
Chemical compounds	**Art centre**	**Osu castle**	**Sakumono**	**Independence square**	**Tema mighty beach**	**Korle gonno beach**	**Labadi beach**	**P**	**% incidence**
p,p'-DDT	3.07±1.70	3.51±0.16	0.77±0.66	1.62±0.58	2.4±2.43	0.33±0.58	0.67±0.61	0.109	66.67
	1.15-4.38	3.39-3.62	0.02-1.29	0.95-2.05	1-5.2	nd-1	nd-1.2		
o'p-DDT	0.82±1.43	0.22±0.32	0.20±0.33	nd	nd	nd	nd	0.546	19.05
	nd-2.47	nd-0.45	nd-0.58	nd	nd	nd	nd		
p'p-DDE	1.98±1.23	0.25±0.21	0.18±0.17	2.47±0.46	nd	nd	nd	0.061	95.24
	1.15-3.38	0.1-0.40	nd-0.33	2.2-3	nd	nd	nd		
p'p-DDD	2.09±2.02	3.01±2.11	1.35±2.14	nd	nd	nd	nd	0.248	38.10
	0.12-4.16	1.52-4.5	0.01-3.82	nd	nd	nd	nd		
o'p-DDD	1.20±2.08	nd	0.20±0.34	0.6±0.35	nd	nd	nd	0.494	9.52
	nd-3.60	nd	nd-0.59	0.6-1.2	nd	nd	nd		
Alpha-HCH	0.62±0.85	0.65±0.40	0.50±0.87	0.57±0.72	nd	nd	nd	0.471	23.81
	nd-1.59	0.37-0.94	nd-1.51	nd-1.38	nd	nd	nd		
Beta-HCH	1.85±1.65	0.76±0.74	3.90±3.98	0.87±0.12	0.8±0.2	1±0.2	0.6±0.53	0.252	85.71
	nd-3.16	nd-1.48	0.56-8.3	0.8-1	0.6-1	0.8-1.2	nd-1		
Gamma-HCH	8.49±3.44	0.98±1.04	3.39±3.42	0.53±0.12	0.47±0.12	0.4±0.00	0.53±0.12	0.001	100
	4.8-11.6	0.24-1.71	1.18-7.32	0.4-0.6	0.4-0.6	0.4	0.4-0.6		
Delta-HCH	1.77±2.21	1.40±0.41	0.49±0.31	0.8±0.00	0.67±0.12	0.4±0.42	0.8±0.00	0.561	95.24
	0.40-4.32	1.11-1.69	0.22-0.82	0.8	0.6-0.8	nd-0.8	0.8-0.8		
HCB	3.71±6.43	1.31±1.85	1.94±3.36	2.19±3.79	nd	nd	nd	0.6	14.29
	nd-11.14	nd-2.61	nd-5.81	nd-6.57	nd	nd	nd		

*nd - not detected (nd < 0.005 ng/g) *values after(±) is standard deviation.

*p - test of significance (p < 0.05 – Significant, p > 0.05 – Not significant)

Table 2. Comparison of concentrations (ng/g-pellet) of DDTs and HCHs in beached plastic resin pellets in other countries.

Location of beaches	DDTs(ng/g)			Total	HCHs(ng/g)				Total	References
	DDT	DDE	DDD		α	β	γ	δ		
Seal Beach, USA	8.34	13.1	15.8	37.2	0.05	0.2	0.15	0.05	0.25-0.45	Ogata et. al. 2009
Quincy Bay, USA	2.03	3.59	1.21	6.83	0.09	0.31	0.11	0.06	0.57	"
Costa Nova, Portugal	1.3	0.25	0.14	1.69	0.09	0.02	0.46	0	0.55-0.56	"
Forth Estuary, UK	0.62	0.8	0.74	2.16	0.03	0.1	0.4	0.39	0.52-0.92	"
Kato Achaia , Greece	0.77	0.83	7.81	9.41	0.28	0.51	0.16	0.09	1.04	"
Izmir, Turkey	8.23	3.47	15.9	27.6	0.2	0.29	0.4	0.23	0.83-1.12	"
Mumbai, India	3.42	1.82	4.34	9.58	0.16	0.34	1.61	0.09	1.77-2.20	"
Rayong, Thailand	2.31	23.3	0.2	25.9	0.17	0.09	0.14	0.08	0.17-0.48	"
Jakarta Bay, Indonesia	1.2	0.96	11.5	13.7	0.19	0.39	0.37	0.14	1.09	"
Minh Chau Island, Vietnam	132	25.3	5.76	163	0.01	0.39	0.15	0.68	1.07-1.23	"
Bay of Maputo, Mozambique	2.97	0.61	0.91	4.49	0.65	0.42	35.4	0.57	36.4-37.1	"
South Durban, South Africa	0.89	1.19	0.35	2.43	-	2.55	30.8	0.58	33.9	"
Shioda, Japan	-	0.16	-	-	-	-	-	-	-	Mato et al. 2001
Kualua Beach, Hawaii	-	-	-	22	-	-	-	-	-	Rios et al. 2007
Kato Achaia , Greece	-	-	-	12.1	-	-	-	-	-	Karapanagioti et al. 2009
Sakumono, Tema	2.89	0.55	4.64	8.08	1.51	11.69	10.16	1.46	24.82	Present study
Labadi beach	2.00	7.4	0.00	9.40	0.00	1.80	1.60	2.40	5.80	"
Osu Castle beach	4.10	3.40	4.51	12.02	1.30	2.28	2.35	3.61	9.54	"

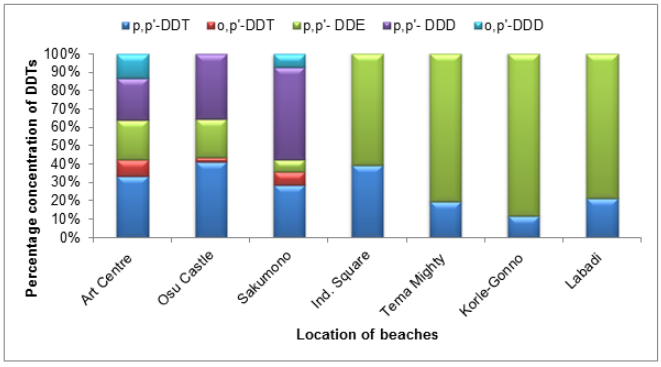

Fig 5. Composition of DDT and its metabolites in plastic pellet.

Additionally, the findings are an indication of the rate of degradation of DDT to DDE in the marine environment under the hot, dry climatic conditions which is characteristic of tropical waters (Guo et al. 2007). Similar trends were observed in water and sediment sampled by Ntow (2005), Kuranchie-Mensah et al. (2011) and fishes also sampled by Kuranchei-Mensah (2009), Adu-Kumi et al. (2010) both from Lake Volta, Lake Bosumtwi, Weija Lake, Densu River basin in Ghana. From these observations, it can be concluded that the DDT levels are decreasing in the country. In Ghana, DDT has been banned from agricultural use in 1985 and restricted for public health purposes under the Stockholm Convention in which Ghana is a signatory. Long term persistence in the environment of this pesticide has been reported in various publications leading to its subsequent restrictions and ban in many countries (Guo et al. 2007; Sarkar et al. 2008; Ogata et al. 2009; Davodi et al. 2011).

The ratio of DDT/(DDE + DDD) can be used to estimate the extent of DDT decomposition or identify recent inputs of DDTs into the ecosystem. In the present study, DDT compositions in the plastic pellets varied considerably with the individual locations. The DDT/(DDE + DDD) ratio had values ranging from 0.13 to 0.78 from the various beaches, suggesting that biodegradation of DDT has occurred in these study areas. Possible new inputs of DDT could, however, not be excluded entirely, because about 10% of the samples had DDT/(DDE +DDD) higher than one.

Moreover, since it had been reported that nearly one (1) tonne of technical DDT was imported into Ghana between 2001 and 2002 (Ghana NIP 2008). The presence of possible new sources of DDTs areas could be responsible for their large variabity in these study.

Variation of HCHs in plastic pellets

All the isomers of HCHs (alpha-HCH, beta-HCH, gamma-HCH and delta-HCH) were detected in all the pellet samples. The maximum concentration of alpha-HCH (0.65 ng/g) was detected in samples from Osu Castle beach while Sakumono beach detected the least concentration of 0.50 ng/g. Beta-HCH concentrations ranged from non detectable to 8.30 ng/g with maximum mean concentration of 1.85 ng/g in pellets sampled at the beach located the Art Centre beach. Statistically, significant variation ($p < 0.05$) was observed among gamma-HCH concentrations. Mean concentration of gamma-HCH and delta-HCH ranged from 0.47 to 8.49 ng/g and 0.47 to 1.77 ng/g from Korle-Gonno and Art Centre beaches respectively (Table 1).

HCHs generally contain the isomers in the following percentages: alpha-HCH 55-80%; beta-HCH 5-14%; delta-HCH 2-16%; gamma-HCH 10-15% with lindane containing more than 99% of gamma-HCH (Guo et. al. 2007).

All the samples tested positive to gamma-HCH thus, 100% incidence ratio, and about 95.24%, 85.71% and 23.81% of the plastic resin pellets sampled tested positive to delta-HCH, beta-HCH and alpha-HCH respectively (Table 1).

In comparison with DDT, HCH had lower concentration. This is expected because HCHs are less bioaccumulative than DDTs, are relatively less lipophilic and have shorter half-life in biological systems. Chemical properties of HCHs also indicate that these compounds are easily evaporated into the air for long distances (Guo et. al. 2007).

Among the HCH isomers, proportions of gamma-HCH gave relatively the highest from some locations with the Art Centre beach having a high percentage of 66.70% followed by Sakumono (40.92%), Labadi (27.59%), Osu Castle (24.66%), Tema Mighty (24.14%), Korle-Gonno (21.43%), Independence Square beaches (19.28%) in that order (Fig. 6).

With respect to the individual isomers, beta-HCH isomer showed high values in the plastic pellet at four locations namely Sakumono, Independence Square, Tema Mighty and Korle-Gonno beaches with mean values of 3.9 ng/g, 0.87 ng/g, 0.80 ng/g and 1.00 ng/g, respectively, and this was compared with results from Seal beach in USA and Kato Achaia beach in Greece also with values of 0.2 ng/g and 0.51 ng/g respectively (Table 2). The reason for higher levels of beta-HCH might be due to the isomerisation of alpha-HCH and gamma-HCH into beta-HCH in seawater and sediment. Moreover, beta-HCH is also more persistence than alpha-HCH and gamma-HCH with respect to microbial degradation and also has a lower volatility (Li et al. 2008; Muralidharan et al. 2009).

The gamma-HCH isomer was also a dominant HCH in the plastic pellet at the Art Centre beach with a mean concentration of 8.49 ng/g. This was compared with results from the southern part of Africa, thus Bay of Maputo in Mozambique and South Durban in South Africa with values of 0.57 ng/g- pellet and 0.58 ng/g- pellet respectively (Table 2), which are lower than the present study. Gamma-HCH (lindane) was marketed in Ghana as Gammalin 20 and until 2002 when its use was discontinued. It was reported to be the most extensively used pesticides on farms and husbandry in Ghana (Awumbila and Bokuma 1994; Adu-Kumi et al. 2011). Thus, high concentrations continue to persist in the environment. High concentration of gamma-HCH in the plastic pellets indicates that lindane has been used in this region probably as a result of runoffs from the farms. The results obtained suggest recent usage of HCH in the environment. The variability of the isomers of HCHs detected in the samples could be attributed to the technical use of HCHs in the country and subsequently bioaccumulation of the contaminant in the aquatic environment.

Concentration of HCB in plastic pellets

The concentration of hexachlorobenzene (HCB) ranged from not detected to 11.14 ng/g. The incidence ratio of HCB in the plastic pellets is 14.29%, suggesting its low occurrence in the environment. Statistically, no significant difference ($p > 0.05$) was observed among the sampled plastic resin pellets

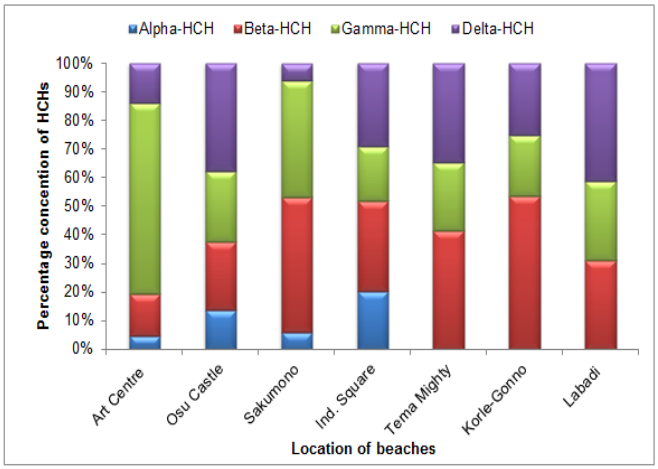

Fig 6. Percentage composition of HCH isomers in plastic resin pellets.

(Table 1). HCB was a fungicide for seed treatment prior to its ban in 1985 in Ghana.It could also be generated as a by-product in the manufacturing process of various chlorine-containing chemicals. Additionally it has been found as an impurity in several pesticides and thus its presence in the plastic pellets could be attributed to these sources. Incineration may also contribute to HCB pollution (Nollet 2000; Ritter et al. 1995).

Variation of CHLs in plastic pellets

The investigated chlordane compounds (CHLs) detected in the pellets from all the locations were trans-chlordane, trans-nonachlor, heptachlor and trans-heptachlor epoxy with the incidence ratio of 42.86%, 38.10%, 33.33% and 19.05% respectively (Table 3). When all the CHLs were summed up Sakumono beach recorded the highest mean concentration of 4.96 ng/g. This level is probably due to the high persistence of heptachlor in the environment since it was banned in 1985. Technical chlordane contains 10% heptachlor (Nollet 2000).

Table 3. Mean concentration and range (ng/g-pellet) of DRINs, CHLs, Endosulphans and Methoxchlor residue in plastic pellets.

	Location of beaches								
Chemical compounds	**Art centre**	**Osu castle**	**Sakumono**	**Independence square**	**Tema mighty beach**	**Korle gonno beach**	**Labadi beach**	**P**	**% incidence**
Heptachlor	1.82±0.00	3.07±2.48	2.30±2.24	0.14±0.24	0.2±0.35	nd	nd	0.172	33.33
	nd-3.63	2.43-5.0	nd-4.47	nd-0.42	nd-0.6	nd	nd		
Trans Heptachlor Epoxy	0.17±0.30	0.10±0.15	0.55±0.96	nd	nd	nd	nd	0.549	19.05
	nd-0.52	nd-0.21	nd-1.66	nd	nd	nd	nd		
Trans Chlordane	1.90±1.10	0.25±0.03	2.11±1.02	1.18±1.46	0.27±0.46	nd	nd	0.001	42.86
	0.96-3.11	0.23-0.73	1.18-3.2	0.13-2.85	nd-0.8	nd	nd		
Trans-Nanochlor	2.21±2.63	0.84±0.09	0.47±0.42	0.64±0.18	nd	nd	nd	0.156	38.10
	0.54-5.24	0.77-0.90	nd-0.83	0.42-0.82	nd	nd	nd		
Alpha-Endosulphan	nd	nd	nd	0.13±0.23	0.2±0.2	0.07±0.12	nd	0.323	23.81
	nd	nd	nd	nd-0.4	nd-0.4	nd-0.2	nd		
Beta-Endosulphan	0.53±0.91	0.22±0.31	nd	0.47±0.42	0.53±0.46	0.67±0.12	0.6±0.0	0.462	57.14
	nd-1.58	nd-0.44	nd	nd-0.8	nd-0.8	0.6-0.8	0.6-0.6		
Endosulphan Sulphate	0.98±1.70	nd	1.07±1.86	nd	0.13±0.23	nd	nd	0.591	14.29
	nd-2.94	nd	nd-3.22	nd	nd-0.4	nd	nd		
Aldrin	1.63±2.19	0.63±0.90	1.12±1.53	0.07±0.12	0.13±0.12	nd	0.07±0.12	0.411	42.86
	nd-4.11	nd-1.27	nd-2.86	nd-0.2	nd-0.2	nd	nd-0.2		
Dieldrin	0.33±0.557	nd	nd	0.2±0.00	0.33±0.12	0.2±0.00	0.07±0.12	0.462	57.14
	nd-0.98	nd	nd	0.2	0.2-0.4	0.2	nd-0.2		
Endrin	0.19±0.33	nd	nd	0.47±0.12	0.47±0.12	0.53±0.12	0.33±0.31	0.011	57.14
	nd-0.5762	nd	nd	0.4-0.6	0.4-0.6	0.4-0.6	nd-0.6		
Methoxychlor	nd	0.2±0.35	0.60±0.80	0.73±0.12	0.8±0.35	0.67±0.12	0.6±0.00	nd	61.90
	nd	nd-0.6	nd-0.80	0.6-0.8	0.6-1.2	0.6-0.8	0.6	nd	

*nd - not detected (nd < 0.005 ng/g) *values after (±) is standard deviation

**p* - test of significance ($p < 0.05$ – Significant, $p > 0.05$ – Not significant

Thus past usage of chlordane may also have contributed to the high level of heptachlor.

Concentration of drins in plastic pellets

Compared to dieldrin and endrin, aldrin recorded the highest concentration among the beaches studied. The aldrin residues were detected in levels ranging from below detection limit to 4.11 ng/g with the highest and lowest mean concentration of 1.63 ng/g and 0.07 ng/g occurring at the Art Centre and Labadi beaches, respectively..

Dieldrin concentration was however lower than aldrin ranging from no detection to 0.98 ng/g in all the studied sites. The highest mean concentration for dieldrin occurred at the Art Centre and Tema Mighty beaches where a value of 0.33 ng/g was recorded.

The concentration of endrin however ranged from not detected to 0.58 ng/g with the maximum mean concentration of 0.53 ng/g recorded in pellets sampled from Labadi beach. Dieldrin and endrin accounted for a total incidence ratio of 57.14% while aldrin was found in 42.86% of the samples analysed (Table 3).

Aldrin was until recently sold under the trade name Aldrex 40 in Ghana and used to treat pests on cocoa. Aldrin undergoes photolytic degradation to dieldrin in sediments (Doyle et al. 1994). From the study, the low levels of dieldrin indicate the slow rate of degradation of aldrin in the pellets studied. A study carried out by Darko et al. (2008) reported lower concentrations of 0.65 ng/g and 0.072 ng/g of aldrin and dieldrin in Lake Bosumtwi in the Ashanti region of Ghana.

Distribution of Endosulphans in Plastic Pellets

Endosulphan and its metabolites (alpha-endosulphan, beta-endosulphan and endosulphan sulphate) were generally detected in most of the locations. Alpha-endosulphan was detected in samples from three out of seven locations with the highest mean concentration of 0.20 ng/g occurring at Tema Mighty beach. The mean concentration of beta-endosulphan ranged from 0.22 to 0.67 ng/g with the minimum and maximum values recorded at Osu Castle and Korle-Gonno beaches respectively. The endosulphan sulphate ranged from 0.13 to 1.07 ng/g at Tema Mighty and Sakumono beaches respectively. Endosulphan sulphate concentrations were relatively higher compared to alpha-endosulphan and beta-endosulphan in the investigated samples (Table 3). This suggests possible degradation of endosulphan to its metabolite endosulphan sulphate in the environment. In Ghana, Adu-Kumi et al. (2012), however, reported very high atmospheric levels of endosulphan (78.88- 185 ng/g) from East Legon and Kwabenya which are suburbs of Accra. They explained that evapouration of endosulphan from contaminated soils occur especially in warm and dry seasons. Thus the tropical climate of Ghana further enhances volatilization rates and favours long-range atmospheric transport of endosulphan. These suggest the occurrence of endosulphan mostly in the air than the marine environment.

Concentration of methoxychlor in plastic pellets

Methoxychlor was detected in six out of seven sampled locations. Total methoxychlor was 9.00 ng/g with mean concentrations ranging from 0.20 ng/g to 0.80 ng/g (Table 3). This high occurrence of methoxychlor might be due to its past usage as an insecticide against flies, mosquitoes, cockroaches, chiggers, and a wide variety of other insects. It was also used on agricultural crops and livestock, and in barns, grain storage bins, home garden, and on pets. Moreover, it also sticks strongly to soil particles (ATSDR 2002).

Conclusions

The results of this work reveal that organchlorine pesticide residues are present in the plastic resin pellets. High concentration of the DDTs (p,p'-DDE, p,p'-DDD, o,p'-DDD, o,p'-DDT, p,p'-DDT) were recorded followed by HCHs (alpha-HCH, beta-HCH, gamma HCH, delta HCH), CHLs (heptachlor, trans-heptachlor epoxy, trans-chlordane, trans-nanochlor), hexachlorobenzene (HCB), DRINs (aldrin, dieldrin, endrin), Endosulphans (alpha-endosulphan, beta-endosulphan, endosulphan sulphate) and methoxychlor. The accumulation of organochlorine pesticide residue on the plastic resin pellets suggests that it can serve as both a transport medium and a potential source of toxic chemicals in the marine environment. Thus a suitable tool for marine pollution monitoring in Ghana.

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References

Adu-Kumi S, Kawano M, Shiki Y, Yeboah PO, Carboo D, Pwamang J, Morita M, Suzuki N (2010) Organochlorine pesticides (OCPs), dioxin-like polychlorinated biphenyls (dl - PCBs), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo furans (PCDD/Fs) in edible fish from Lake Volta, Lake Bosumtwi and Weija Lake in Ghana. Chemos 81:675–684

Adu-Kumi S (2011) Exposure levels, Environmental fate modelling and human health risk assessment of Lindane in Ghana. Mphil Thesis. pp 71-85

Adu-Kumi S, Kares R, Literak J, Borukova J, Yeboah PO, Carboo D, Darko G, Osae S, Klanova J. (2012) Levels and seasonal variations of organochlorine pesticides in urban and rural background air of southern Ghana. Environ Sci Pollut Res 19:1963-1970

Afful S, Anim A. K, Serfor-Armah Y (2010) Spectrum of Organochlorine Pesticide Residues in Fish Samples from the Densu Basin. Res J Environ Earth Sc 2(3):133-138

ATSDR (2002) Toxicological profile for methoxychlor. US Department of Health and Human Services, Public Health Service, Atlanta, GA. pp 1-2

Awumbila B and Bokuma E (1994) Survey of pesticides used in the control of ectoparasites of farm animals in Ghana. Trop Anim Health Prod 26(1):7-12

Blankson-Arthur S, Yeboah PO, Golow AA, Osei Tutu A, Denutsui D (2011) Levels of Organochlorine Pesticide Residues in Grasscutter (Thryonomys swinderianus) Tissues. Res J Environ Earth Sci 3(4): 350-357.

Carpenter EJ, Anderson SJ, Harvey GR, Miklas HP, Peck BB (1972) Polystyrene spherules in coastal waters. Science 178:749–750. doi:10.1126/science.178.4062.749

Darko G and Acquaah SO (2007) Levels of organochlorine pesticides residues in meat. Int J Environ SciTechnol 4 (4):521-524

Darko G, Akoto O, Oppong C, 2008 Persistent organochlorine pesticide residues in fish, sediments and water from lake Bosomtwi. Chemos, 72: 21-24

Davodi M, Esmaili-Sari A, Bahramifarr N (2011) Concentration of polychlorinated biphenyls and organochlorine pesticides in some edible fish species from the Shadegan Marshes. Ecotoxicolo Environ Saf 74:294–300

Day RH, Wehle DHS, Coleman FC (1985) Ingestion of plastic pollutants by marine birds. Pages 344-386 in Shomura, R. S, and H. O. Yoshida (Eds.), Proceedings of the Workshop on the Fate and Impact of Marine Debris, November 27-29, 1984, Honolulu, Hawaii. NOAA Tech. Mem. NOAA-TM-NMFS-SWFC-54.Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, DC. Diet study. Environment International (EI-02237). pp 1- 8

Doyle ME, Steinhart CE, Cochrane BA (1994) Food Safety (1st edn) University of Wisconsin-Madison Food Research Institute CRC. pp. 568

Endo S, Takizawa R, Okuda K., Takada H, Chiba K., Kanehiro H, Ogi H, Yamashita R, Date T (2005) Concentration of polychlorinated biphenyls (PCBs) in beached resin pellets: variability among individual particles and regional differences. Mar Pollut Bull 50(10):1103–1114 doi:10.1016/j.marpolbul.2005.04.030

Essumang DK, Togoh GK, Chokky L (2009) Pesticide Residues in the Water and Fish (Tilapia) Samples from Lagoons in Ghana. Bull Chem Soc Ethiop 23 (1):19-27

Ghana National Implementation Plan (2008) http://www.pops.int/ (Accessed 17th May 2012)

Ghana Statistical Service (2010) Population & Housing Census of Ghana, Summary Report of Provisional Results. pp 1-22

Guo JY, Zeng EY, Wu FC, Meng XZ, Bi-Xian Mai BX, Luo XJ (2007) Organochlorine pesticides in seafood products from southern china and health risk assessment. Environ Toxicol Chem 26(6):1109–1115

Karapanagioti HK and Klontza I (2007) Investigating the Properties of Plastic Resin Pellets Found in the Coastal areas of Lesvos Island. Global NEST Journal 9(1):71-76

Karapanagioti HK. and Klontza I (2008) Testing phenanthrene distribution properties of virgin plastic pellets and plastic eroded pellets found on Lesvos island beaches (Greece). Mar Environ Res 65:283–290

Kuranchie-Mensah H, Palm LMN, Manukure SA, Afful S, Adjei- Martey G, Arthur JK (2011) Assessment of organochlorine pesticides and polychlorinated biphenyls levels in fishes from the Volta Lake, Ghana and their suitability for human consumption. Elixir Food Science 41: 5982-5990

Kuranchie-Mensah H (2009) Studies of Organochlorine pesticide residue in fish, water and sediment from the Densu River Basin. Mphil Thesis. pp 1-114

Li X, Gan Y, Yang X, Zhou J, Dai J, Xu M (2008) Human health risk of organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in edible fish from Huairou Reservoir and Gaobeidian Lake in Beijing, China. Food Chem 109: 348-354

Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C, Kaminuma T (2001) Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ Sci Technol **35**:318-324. doi:10.1021/es0010498

Mato Y, Takada H, Zakaria MP, Kuriyama Y, Kanehiro H (2002) Toxic chemicals contained in plastic resin pellets in the marine environment -spatial difference in pollutant concentrations and the effects of resin type-. Kankyo Kagakukaishi 15: 415-423

Moore CJ, Lattin GL, Zellers AF (2005) A Brief Analysis of Organic Pollutants Sorbed to Pre and Post- Production Plastic Particles from the Los Angeles and San Gabriel River Watersheds. Algalita Marine Research Foundation, 148 Marina Drive, Long Beach, CA 90803. pp 1-9

Muralidharan S, Dhananjayan V, Jayanthi P (2009) Organochlorine pesticides in commercial marine fishes of Coimbatore, India and their suitability for human consumption. Environ Res 109:15-21

Nollet LML (2000) Handbook of Water Analysis Food Science and Technology (1st edition).CRC Pp. 920

Ntow J (2001) Organochlorine Pesticides in Water, Sediments, crops and human fluids in a farming community in Ghana. Arch Environ Contam Toxicol 40(4): 557-563

Ntow WJ (2005) Pesticide residues in Volta Lake, Ghana. Lake and Reservoirs: Res Manage 10:243-248

Ogata Y, Takada H, Mizukawa K., Hirai H, Iwasa S, Endo S, Mato Y, et al (2009) International Pellet Watch: Global monitoring of persistent organic pollutants (POPs) in coastal waters. 1. Initial phase data on PCBs, DDTs, and HCHs. Mar Pollut Bull 58:1437–1446

Osei Tutu A, Yeboah PO, Golow AA, Denutsui D, Blankson-Arthur S (2011) Organochlorine Pesticides Residues in the Breast Milk of Some Primiparae Mothers in La Community, Accra, Ghana. Res J Environ Earth Sci 3(2):153-159

Rios LM, Moore C, Jones PR (2007) Persistent organic pollutants carried by synthetic polymers in the ocean environment. Mar Pollut Bull 54:1230–1237

Ritter L, Solomon KR, Forget J, Stemeroff M, O'Leary C (1995) The International Programme on Chemical Safety (IPCS) within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC). pp 1-43

Sarkar SK, Bhattacharya BD, Chatterjee M, Alam A, Satpathy KK, Jonathan MP (2008). Occurrence, Distribution and Possible Sources of Organochlorine Pesticide Residues in Tropical Coastal Environment of India: An Overview. Environ Int 34:1062-1071

Takada H, Mato Y, Endo S, Yamashita R, Zakaria MP (2006) Pellet Watch : Global Monitoring of Persistent Organic Pollutants (POPs) using Beached Plastic Resin Pellets. pp 1-2

Yatawara M, Devi LN, Shihua Q (2009) Persistent Organic Pollutants (POPs) in Sea food of China- A review. J Am Sci 5(5):164-174

Zhou P, Zhao Y, Li J, Wu G, Zhang L, Liu Q, Fan S, Yang X, Li X, Wu Y (2011) Dietary exposure to persistent organochlorine pesticides in 2007 Chinese total.