RESIDUAL ENDOSULFAN CONCENTRATIONS IN SOME FISH SPECIES OF GÖKSU DELTA, NORTH-EASTERN MEDITERRANEAN

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ABSTRACT

Göksu Delta is a natural wetland, consisting of two main lakes connected with a channel, together with various little lagoons and lakes. The Delta is surrounded by a vast agricultural area where different kinds of products are grown during the whole year, and various pesticides, such as endosulfan, are used extensively. In the present study, residual endosulfan concentration of four fish species; *Mugil cephalus, Alburnus orontis, Cyprinus carpio* and *Clarias lazera* have been studied. Totally, 74 fish samples have been collected from Akgöl, Paradeniz and from the water channels during the period of June 2002-November 2002. The age, length and weight of the fish samples were also determined. Residual levels of total endosulfan, α-endosulfan (α-ES), β-endosulfan (β-ES) and endosulfan sulfate (ESS) have been analyzed in both liver and muscle tissues of the fish samples according to the modified GC/μECD Standard Method. Endosulfan (α-ES, β-ES, ESS) levels were found to be changing from one fish species to another. The highest endosulfan concentration of 328.60 ng/g dry weight (dw) was observed in liver tissue of *Alburnus orontis*. On the other hand, the mean values for muscle tissue of fish samples were not so high. Residual endosulfan levels in muscle tissue of fish samples were 7.37±3.76 ng/g dw for *Mugil cephalus*, 6.94±2.20 ng/g dw for *Alburnus orontis*, 11.23±7.23 ng/g dw for *Cyprinus carpio,* and 13.51±4.95 ng/g dw for *Clarias lazera*, indicating a general accumulation trend, particularly in lipids of fish tissues.

KEYWORDS: Organochlorine, endosulfan residues, fish tissue, wetland, Göksu Delta

1 INTRODUCTION

Göksu Delta is an eutrophic wetland of 1500 km^2 at the Eastern Mediterranean Coast of Turkey. The Delta is composed of an alluvium which is transported by Göksu River, and it is one of the 8 wetland areas in Turkey under the protection of Ramsar Convention [1]. As can be seen from Fig. 1, two large lakes are situated on the western side of the Delta where Göksu River reaches the sea. One of them is Paradeniz Lagoon, having 40 km^2 of surface area and brackish waters due to its partial connection to the sea. Akgöl is having 120 km^2 of surface area, and it is an eutrophic fresh water lake. Akgöl and Paradeniz are connected to each other with a water channel. The northern parts of these lakes are surrounded by agricultural areas. [2]. Mediterranean type of climate allows very intense agricultural activities around Göksu Delta, almost throughout the year. Therefore, tremendous amount of fertilizers and pesticides are applied to the region in order to increase agricultural productivity. It has been reported that annually 94 tons of pesticides and 431 tons of mineral manure are used in the surrounding land of Göksu Delta [3].

Endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzo(e)dioxathiepin-3-oxide) is an organo-chlorine compound which is used as a large spectrum of insecticides. It is commonly used for protecting grain, tea, fruit, vegetables, cotton, tobacco and wool. Technical endosulfan contains α-endosulfan [6,9-methano-2,4,3-benzodioxathiepin,6,7,8,9,10,10-hexachloro-1,5,5a, 6,9,9a-hexahydro-,3-oxide(3α,5aβ,6α,9aα, 9β)-] with 94 % of purity and β-endosulfan contains [6,7,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodiozathiepin-3-oxide (3α,5aβ,6β,9aβ, 9α)-] isomers. It was reported that the ratio of α- and β- stereoisomers are approximately 7:3 [4-7]. Several researchers reported that endosulfan sulfate [6,7,8,9,10,10-hexachloro-1,5,5a,6,9, 9a-hexahydro-,6,9-methano-2,4,3-benzodiozathiepin-3,3-dioxide] is the primary degradation product of endosulfan [7-11].

Endosulfan is generally adsorbed by soil particles just after application to the field. Some part of endosulfan in soil is transported to the atmosphere by evaporation, the other part is degraded within the soil, and the rest of it persists there for years. Adsorbed endosulfan fraction can be washed away from soil by rain waters, and then transferred to the surface water-bodies. A small amount of endo-

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sulfan in water degrades with time. Degradation of endosulfan in water takes place within one day, or within a couple of months depending on the physical conditions. Partially, endosulfan is transported to the atmosphere by evaporation. Solubility of endosulfan in water is 60-100 µg/L at 25 °C [12]. Since it is slightly soluble in water, endosulfan exists in ground waters in trace amounts. Concentration of endosulfan within the bodies of aquatic animals can be much higher than its concentration in water [13].

TABLE 1 - The amount of endosulfan used for various agricultural products in Mersin in 2004 (Turkish Ministry of Agriculture and Rural Areas, 2004).

Products	Amount used	Code and concentration	Amount of endosulfan (kg)
Cotton	1,125 kg	35 WP-%32.9	370
Peach	2,962 kg	35 WP-%32.9	975
Vineyard (grape)	6,000 kg	35 WP-%32.9	1 974
Vegetables in field	2,950 kg	35 WP-%32.9	971
Vegetables in field	18,168 L	EC-369 g/L	6 704
Greenhouse vegetables	6,192 L	EC-369 g/L	2 285
Hard grainy (peach, apricot, plum, etc.)	315 L	EC-369 g/L	116
Potatoes	150 L	EC-369 g/L	56
		TOTAL	13452

The toxic effect of endosulfan on juvenile rainbow trout (*Oncorhynchus mykiss*) in relation to water quality and size of the fish have been investigated by Çapkın *et al*. (2006) [14], and it has been found that more than 1.3 µg/L of endosulfan concentration in fresh water has toxic effects on this kind. In CODEX Alimentarus (2010) [15], maximum endosulfan concentration that can be allowed for meat and oily food is given as 0.2 mg/kg. Henry and Kishimba (2006) [16] also notified that maximum presence level of total endosulfan in fish is 0.6 mg/kg (MARL, Maximum Acceptable Residue Levels). Although the usage of this pesticide has officially been forbidden, and its certificate has been cancelled in the beginning of 2008, it is still widely used in the studied area. The amount of endosulfan used as a pesticide for various agricultural products in Mersin Region in 2004 is presented in Table 1.

2 MATERIALS AND METHODS

2.1. Sampling Stations

Fish samples were taken from Akgöl, Paradeniz, and from the water channel which connects the two lakes (Fig. 1). Sampling was performed in spring and autumn 2002. The exact locations of the sampling stations were identified with Etrex 12 Chanel GPS device. The coordinates of the sampling stations are given below:

1. Paradeniz (36S 0591333, UTH 4018375)
2. Water channel (36S 0590148, UTH 4018918)
3. Akgöl (36 S 0585729, UHT 4020105)

2.2. Characteristics of the Monitored Fish Species

Fish samples were selected according to their habitats and nutrition styles. Their commercial value which is an indicator of their consumption rate as a food has also been taken into consideration. For this purpose, four fish spe-

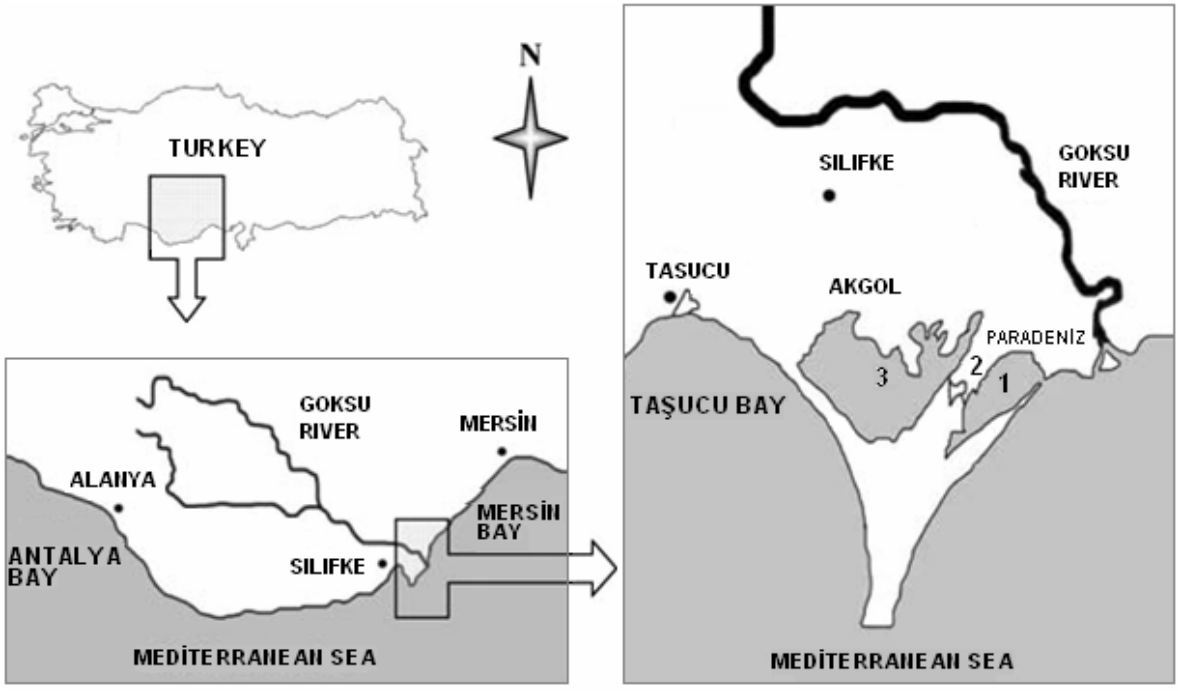

FIGURE 1 - Fish sampling stations: (1) Paradeniz, (2) Water channel, (3) Akgöl.

cies, all are native in the Delta, were selected. Totally, 16 samples of *Cyprinus Carpio*, 23 samples of *Clarias lazera*, 21 samples of *Mugil cephalu,s* and 14 samples of *Alburnus orontis* have been analyzed for residual α-ES, β-ES and ESS concentrations.

Cyprinus carpio (Linnaeus, 1758) (Carp-Cyprinidae) is a commercially valuable omnivorous fish [17-19]. *Cyprinus carpio* samples were taken from Akgöl (station 3).

Clarias lazera (Valenciennes, 1840) is very much similar to *Clarias gariepinus*, (Burchell, 1822), both of them are carnivorous types of fish taking place in the first level of the food pyramid [20-22]. They can mostly be found in Göksu Delta. *Clarias lazera* samples were taken from Akgöl (station 3).

Mugil cephalus (Linnaeus, 1758) (Grey Mullet-Mugilidae) is a kind of detritivorous fish. It feeds on sea bottom plants and shellfish. They have high tolerance against environmental changes. They live in lakes, sea, deltas and stream mouths [23]. They can mostly be found in water channels and lakes in Göksu Delta. *Mugil cephalus* samples were taken from water channel (station 2).

Alburnus orontis (Sauvage, 1882) (Bleak fish-Cyprinidae) is a kind of carnivore. Since this species is not commercially valuable as an edible fish, it is usually preferred to be used as a feed in fish farms [24, 25]. *Alburnus orontis* samples were taken from Paradeniz (station 1). Fishing in Göksu Delta has totally been forbidden after this region has been declared as a Privately Protected Environment, in 1990.

2.3. Analysis Methods

2.3.1. Preparation of Fish Samples for Analysis

Fish samples were collected from lagoons and lakes in Göksu Delta with the method of paying away. All samples were put into an icebox, and then transferred to the laboratory within 3 h. Samples were covered with aluminum foil and labeled. They were kept in a deep freezer at –20 °C until analysis.

Analytical-grade branded chemicals from Merck, Sigma, Aldrich, and Riedel have been used in pesticide analysis. α-ES, β-ES and ESS standards and the characteristics of internal standards are given below. Characteristics of the used pesticides and internal standards (6890 model Hewlett Packard GC; Dr. Ehrenstorfer) are listed in Table 2.

A Hewlett Packard 6890 equipped with an auto sampler, a micro electron capture detector (μECD), and a HP-5 crosslinked 5% phenyl-methyl siloxane, 30 m x 0,32 mm x 0,25 μm film thickness column was used for GC pesticide analyses. The temperature of μECD was kept at 330 °C. Nitrogen gas was used both as a carrier and make up gas in the μECD at a flow-rate of 6.9 ml/min and 60 ml/min, respectively. The injection volume was 1 μl, with splitless injection mode. The temperature of the injection port was 250 °C. The following oven temperature program was applied: 80 °C (beginning heat), 30 °C/min to 195 °C, 5 °C/min to 250 °C, and 120 °C/min to 290 °C (finally, held for 5 min) [26, 27].

During the analyses, slightly modified methods of Reference Method No 65 (2001) [28], Reference Method No 57 (1990) [29], Reference Method No 6 (1993) [30], Reference Method No 12 (1991) [31], Reference Method No 71 (1996) [32], and IAEA have been used.

Each pesticide was determined by analyses of internal standards. For this purpose, blank samples have been prepared and the same procedures have also been applied to these samples in order to determine the possible losses during extraction and column processes. Preparation of fish samples for GC pesticide analyses have been carried out at the Institute of Marine Sciences of the Middle East Technical University (IMS-METU). Organic Laboratory of this Institute had attended to UNEP's Regional Seas Intercalibration Program used by 83 laboratories from 44 countries. Reference samples supplied from this Intercalibration Program have been analyzed for OC pesticides, and the mean recovery for endosulfan was found to be 87 % [33].

2.3.2. Residual Endosulfan Analysis

Before the analysis, fish samples were weighed and their lengths were measured. Age was determined from scales and the gender was identified by autopsy. Muscle and liver tissues of fish samples were extricated by a scalpel. Weighed fish muscle and liver tissues were freeze-dried until its dry/wet mass ratio reaches approximately 0.2. Dry sample was triturated by being pounded in a porcelain mortar, and then, it was placed in a Soxhlet extraction apparatus within a thimble. After addition of 1 ng internal standard (α-endosulfan 1D4) into each of the samples, they were extracted for 8 h with the mixture of 250 ml (1:1) n-hexane-dichloromethane (n-hexane: Merck 4371, di-

TABLE 2 - Characteristics of the used pesticide and internal standards (6890 model Hewlett Packard GC).

Standards (Dr. Ehrenstorfer)	Catalog No	CAS No	Chemical formulation	Purity %	Mol mass g/mol
α-ES	L13121000CY	959-98-8	$C_9H_6Cl_6O_3S$	99.30	406.93
β-ES	L13122000CY	33213-65-9	$C_9H_6Cl_6O_3S$	98.50	406.93
ESS	L13133000CY	1031-07-7	$C_9H_6Cl_6O_4S$	99.40	422.93
Internal standard	Catalog No	Lot No	Chemical formulation	Purity %	Mol mass g/mol
α-Endosulfan 1D4	XA13121100AC	20205AC	$C_9H_2Cl_6O_3SD_4$	99.00	406.93

chloromethane: Merck 6054) with approximately 5-6 siphonages per h [27]. The capacity of the extract was firstly reduced to 15 ml in a rotary evaporator (0.1 MPa and 30 °C) and then, to approximately 10 ml with nitrogen. Extractable organic matter of the samples was also determined. Fat content of the samples, having more than 150 ng/g of fat, was reduced by H_2SO_4. After the capacity was reduced to 15 ml in a rotary evaporator, the sample was taken into a tube, and the volume was reduced to approximately 1 ml with nitrogen.

The compounds within the extracted samples were classified by using a florisil column, previously been extracted in a Soxhlet apparatus using methanol for 8 h, in order to remove any possible contamination. The extract, reduced to 1 ml, was put into the florisil column. It was then eluted carefully with 70 ml of hexane, and the first fraction was collected (the first group of compounds; HCH, heptachlor, aldrin, op-DDE, pp'-DDE and PCB). Then, the column was eluted by 50 ml of a mixture containing 70% hexane and 30% dichloromethane, and the second fraction was collected (the second group of compounds; α-HCH, β-HCH, γ-HCH, δ-HCH, α-chlordane op-DDD, pp'-DDD, op-DDT, pp'-DDT). The third fraction was eluted with 40 ml of pure dichloromethane (the third group of compounds; heptachlor epoxide, α-ES, dieldrin, endrin, β-ES, ESS). The extract capacity of each group was reduced to approximately 1 ml with nitrogen stream in a rotary evaporator, and the sample was put into a vial (2 ml Clear Crimp Vial Cap, Std. Seal 100 piece 5/pk). α-ES, β-ES, ESS and α-endosulfan 1D4 were analyzed at first, then the second and third group of extracts. Sample capacity injected was 1 µl. The same procedures were also applied to α-ES, β-ES, ESS and α-endosulfan 1D4 standards in order to obtain the calibration curves.

The mean recovery of the internal standard, which was added to the sample, was 85% (min. 67%, max. 103%). This value was determined for each of the samples. Endosulfan concentrations of the calibration standards were changing between 0.001-0.625 ng/µl while internal standard concentrations were changing between 0.0005-0.0018 ng/µl. The detection limits for endosulfan and α-endosulfan 1D4 were 0.03 ng/g and 0.04 ng/g, respectively.

3 RESULTS AND DISCUSSION

3.1. Physical Properties of Fish Samples

Fish samples were taken from Paradeniz (station 1), water channel (station 2), and Akgöl (station 3) (Fig. 1). Sampling was performed twice in 2002, June and November. Some measured physical properties of fish samples are given in Table 3.

No significant differences have been observed between the lipid levels of muscle tissues among the dry and wet season samples (Table 3). On the other hand, lipid contents of almost all liver tissues were found to be relatively higher than those of fish muscle. Additionally, lipid contents of liver displayed seasonal variation, with an increase in cold and wet season. This result can be explained by the metabolism of fish which is closely related to the heat balance of the organisms. Lower lipid concentration of dry season's liver samples might show that the most energy gained by fish during this hot period is spent for breeding and growth of the organism [24, 34-36].

In our study, the mean lipid contents of muscle and liver tissues of *Cyprinus carpio* were found to be 3.26 and 12.28%, respectively (Table 2). The lipid percentage of muscle and liver tissues of *Cyprinus carpio* were reported to be 0.66 and 5.72%, respectively [44]. In another study, the lipid concentration of muscle tissue of *Clarias gariepinus,* fish native to Quémé River (Republic of Benin) and being similar to *Clarias lazera,* was reported as 4.2% [26]. Our result is very close to this value, and we found 3.37% (as a mean) of lipids in muscle tissue of *Clarias lazera* samples.

3.2. Residual Endosulfan Concentrations

The results of the residual α-ES, β-ES, ESS and ΣES concentrations measured in muscle and liver tissues of four fish species are presented in Table 3. Endosulfan concentrations have been measured in the lipid fraction, extracted from the freeze-dried muscle and liver tissues of fish samples. However, the results were given on the dry mass basis of either muscle or liver tissues instead of lipid content. This conversion was made by means of the lipid content of every particular freeze-dried tissue sample. Relatively higher residual pesticide levels have been ob-

TABLE 3 - Physical properties of fish samples.

		Mugil cephalus		*Alburnus orontis*		*Cyprinus carpio*		*Clarias lazera*	
Station		(2)		(1)		(3)		(3)	
		n_J=10	n_N=11	n_J =7	n_N =7	n_J =7	n_N =9	n_J =10	n_N=13
Age		1.2	1.2	1.1	1.4	2.0	2.0	5.1	2.1
Length (cm)		18.3±2.6	21.6±3.8	15.43±2.4	16.9±2.5	15.9±3.0	17.0±2.5	56.2±4.3	27.3±3.6
Mass (g)		64.6±8.9	60.3±17.1	34.9±4.2	44.8±15.8	117.0±56.5	119.3±53.2	569.0±174.9	117.6±85.3
Lipid (%)	Muscle	3.23	3.31	3.77	3.80	3.08	3.43	3.16	3.57
	Liver	5.43	7.11	5.80	21.42	8.43	16.13	8.21	59.60
Sexuality	F	6	7	7	7	6	7	10	10
	M	4	4	-	-	1	2	-	3
Dry/Wet		0.23	0.21	0.20	0.20	0.21	0.21	0.19	0.20

F: female, M: male, J: June, N: Novembe,r n: sample number

TABLE 4 - Residual pesticide concentrations (ng/g dw) in muscle and liver tissues of fish samples.

Pesticide (ng/g)		*Mugil cephalus* (2)		*Alburnus orontis* (1)		*Cyprinus carpio* (3)		*Clarias lazera* (3)	
		n_J=10	n_N=11	n_J =7	n_N =7	n_J =7	n_N =9	n_J =10	n_N=13
Muscle	α-ES	0.90±0.37	4.82±1.79	2.85±0.93	3.95±1.00	6.60±3.01	7.32±3.36	3.68±0.44	6.18±3.48
	β-ES	0.70±0.26	3.11±2.16	1.72±0.58	2.39±1.10	2.03±1.41	1.75±1.00	2.05±0.61	3.28±1.44
	ESS	0.69±0.28	4.70±2.85	1.21±0.45	1.75±0.89	1.16±0.30	1.23±0.64	5.35±0.75	6.47±4.49
	ΣES	2.29±0.71	12.63±5.69	5.78±1.52	8.09±2.63	9.79±4.34	10.31±4.94	11.09±0.90	15.93±6.55
Liver	α-ES	23.82	108.38	38.33	287.21	28.92	67.58	2.13	48.68
	β-ES	1.89	20.64	14.33	11.59	8.95	15.22	0.61	32.41
	ESS	1.24	25.21	12.15	29.80	2.52	3.61	1.84	21.61
	ΣES	26.95	154.23	64.81	328.60	40.40	80.41	4.58	102.70

J: June, N: November, n: sample number, (1), (2), (3): sample station

served in liver tissues of almost all samples. Similar to our study, Ayaş *et al*. (1997) [37] also found relatively higher residual OC pesticides in liver tissue of *Cyprinus carpio* samples (mean value 4217 ng/g for o,p' DDT).

A comparison among muscle tissues of fish samples reveals that the highest ΣES concentration of 15.93±6.55 ng/g (dw) belongs to *Clarias lazera* caught from Akgöl (station 3) in November (wet season) (Table 4). Total endosulfan concentrations of α- and β– isomers (α-ES+β-ES) in muscle tissue of *Clarias lazera* samples of Akgöl were calculated to be 27.02 ng/g (dw). On the other hand, a quite high (α-ES+β-ES) concentration of 53.25 ng/g has been reported in muscle tissue of *Clarias gariepinus* in Quéme River [26]. This value is approximately twice higher than our value. The lowest ΣES concentration of 2.29±0.71 ng/g (dw) has been observed in muscle tissue of gray mullets (*Mugil cephalus*) collected from station 2 in June (dry season) (Table 4). Kalyoncu *et al*. (2009) [38] reported a quite higher ΣES concentration of 9.53 ng/g (dw) for gray mullet samples of Göksu Delta. The same researchers have also analyzed some *Mugil cephalus* samples taken from markets in Konya (Turkey), and they reported a ΣES concentration of 12.9 ng/g (dw). This value is not comparable to our value, since it was given on wet weight basis.

Total residual endosulfan concentrations of muscle and liver tissues of four fish species are also compared in Fig. 2. Relatively high residual pesticide levels have been measured in liver tissues of almost all samples. Similar to our measurements, Serrano *et al*. (2008) [39] and Guo *et al*. (2008) [40] have also measured relatively higher residual ΣOC pesticides in liver tissue of fish samples.

Seasonal variation can easily be noticed from Fig. 2, with higher residual ΣES levels in all species of rainy season's samples. The reason of this result can be explained by the formation way of Göksu Delta. The delta is formed with the regular annual floods of Göksu River. This formation shows a dynamic structure. Göksu River floods occur in rainy periods and cause agricultural soils drift into aquatic environment. The river flows in the shape of channels by dividing into branches in the delta, and leaves all the accumulation collected with the flood there. Slowing down the water flow within the delta is mostly ended in nearby lakes before reaching the sea. As it has already been mentioned in the introduction section, Göksu Delta is a region where agricultural activities are densely carried out beyond the privately protected area. Agricultural activities continue all the year round, and products can be obtained four times per year. The region shows the typical characteristics of the Mediterranean type of climate which is warm and rainy in winter, but hot and dry in summer. Water level decreases in lakes and water channels where irrigated farming is performed during summer. However, solid matter content decreases because there is no drift in drainage waters from agricultural areas. Solubility of endosulfan in water is 60-100 µg/L at 25 °C [12]. It is slightly soluble in water and mostly adsorbed on the soil particles [41]. As a result of this, it is thought that transportation of residual pesticides to the aquatic ecosystems decreases in dry season and increases in wet season.

Muscle (Fig. 3) and liver tissues (Fig. 4) of all fish species, except muscle tissue of *Clarias lazera*, have higher concentrations of α-ES than β-ES and ESS. This is a general result usually encountered in this type of studies [16]. One of the reason for the detection of higher concentrations of α-ES than β-ES in fish might be the presence of α-ES in higher concentrations (70%) than β-ES in technical endosulfan. Additionally, it has been notified that β-ES is splitted faster than α-ES by fish metabolism [42]. Therefore, the finding of β- isomer in fish samples can be accepted as an indicator of time elapsed between the application of endosulfan and the sampling of fish [43].

During the period of 1991-1993, residual organochlorine (OC) pesticides (DDT and DDT derivatives, α-BHC, β-BHC, lindane, aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide) in various environmental and biota samples of Göksu Delta have been investigated by Ayaş *et al*. (1997) [37], and the existence of 13 OC pesticides in water, sediment, soil, crab, blue crab, fish and different species of water birds have been proven. Even though, the same species of fish and the same species of OC pesticides have not been monitored by Ayaş et al. [37] as in our study. This is the only reference research performed on the residual OC pesticides in biota samples of Göksu Delta. Carvalho *et al*. (2009) [27] have measured residual α-ES, β-ES, ESS concentrations in fish and oyster samples in a natural protection area of Laguna de Terminos in

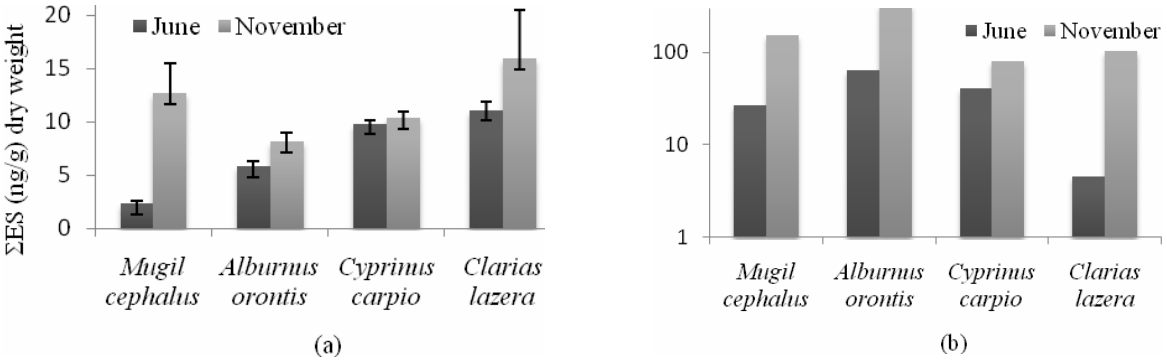

FIGURE 2 - Total endosulfan (ΣES) concentrations in fish muscle (a) and liver (b) tissue.

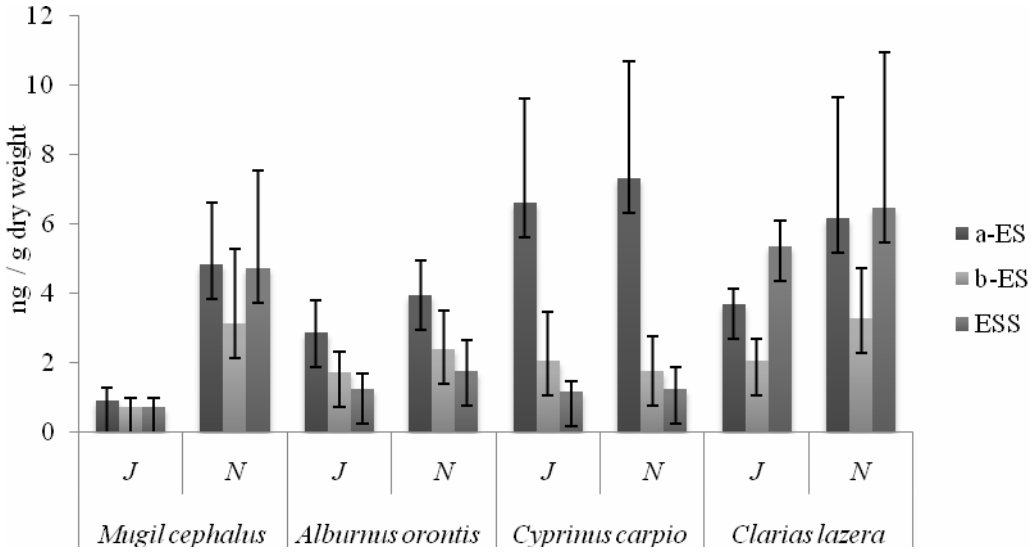

FIGURE 3 - Residual endosulfan concentrations in muscle tissue of fish samples.

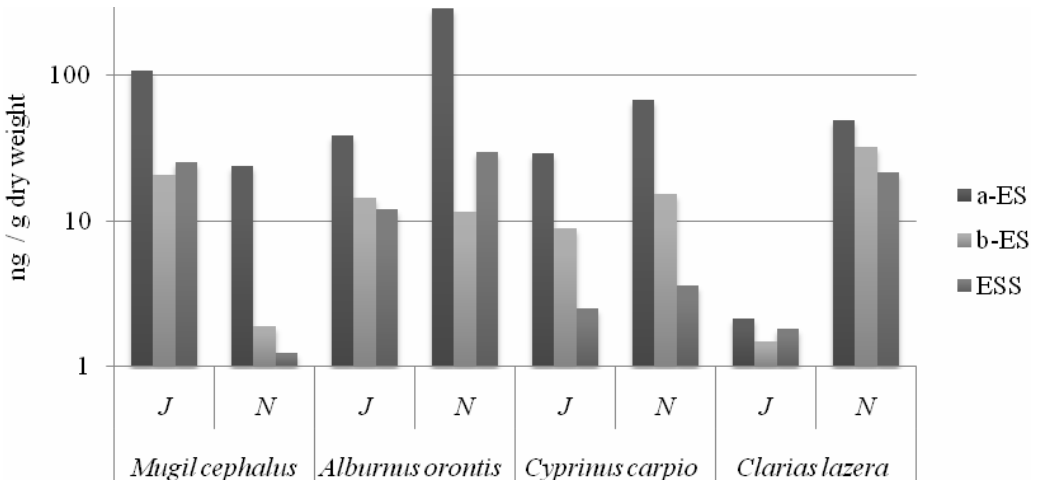

FIGURE 4 - Residual endosulfan concentrations in liver tissue of fish samples.

Mexico. They reported a mean ΣES concentration of 0.385 ng/g (dw) for biota samples, which is approximately 10^1 orders of magnitude lower than our overall mean ΣES concentration of 3.52 ng/g (dw) found for all fish samples of Göksu Delta. Another study has been conducted in Southern Lake Victoria, Tanzania, and a concentration range of 0.4–42.0 ng/g (ww) has been reported for (α-ES+β-ES) in Nile tilapia (onmivorous) and Nile perch (carnivorous) samples [16]. This range is not comparable to our overall mean (α-ES+β-ES) concentration of 6.66 ng/g (dw), since they are presented on different (wet) basis.

4 CONCLUSION

Residual endosulfan concentrations of four fish species; *Mugil cephalus, Alburnus orontis, Cyprinus carpio* and *Clarias lazera*, all native in Göksu Delta, have been studied in the year 2002. Totally, 74 muscle tissues of fish samples have been analyzed, and overall mean values of 4.54, 2.13, and 2.82, ng/g (dw) were found for α-ES, β-ES and ESS, respectively, while the general mean concentration of ΣES in fish muscle was 9.49 ng/g (dw). Relatively higher OC pesticide concentrations have been observed in liver tissues of fish; the overall mean concentration of ΣES in fish liver was 100.34 ng/g (dw). According to CODEX Alimentarus (2010) [15], the maximum endosulfan concentration that can be allowed for meat and oily food is 0.2 mg/kg. If we assume this concentration as a maximum acceptable residue level of endosulfan, then we can safely conclude that this limit is never exceeded in our study. However, the presence of endosulfan in varying concentrations in all fish samples is an indicator of the bioaccumulation of this OC pesticide within the Delta. Consequently, this compound will enter the food-chain, will move along the trophic level, and will be threatened for all ecosystems including human health. Besides, Göksu Delta is a natural wetland under protection. Protecting and transferring its natural wealth to future is a great responsibility, not only for Turkey but also for the entire world.

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