POPs IN SEDIMENTS AND FISH FROM THE SALTON SEA, CALIFORNIA, USA

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Introduction

The Salton Sea is the largest manmade lake in California and the largest continuous below-sea-level waterbody in North America. It was created in 1905 when an accidental breach of a canal temporarily diverted Colorado River water into a natural depression below sea level. Since its accidental beginning, the Salton Sea has been an environmental and recreational attraction in Southern California. It supports a major sport fishery and has long been a popular area for boater and other recreationalists. Each day in the winter, it is also home to 4 million birds[1]. Because of these multiple uses, pesticide contamination of Salton Sea fish may adversely impact both the natural and social ecosystems of Southern California.

The Salton Sea has historically received significant agrichemical input including pesticides utilized throughout the past several decades[2]. The rivers that flow into the Sea contain numerous pesticides, fertilizer, and industrial waste[3]. Due to the elevated temperatures in the area, water evaporates increasing salinity to 45 ppt. Massive fish and bird die offs, as well as eutrophication, are also commonly observed[4]. The Salton Sea is officially designated by the State of California as an agricultural drainage reservoir.

The purpose of this study was to evaluate persistent organochlorine compounds concentrations in sediments and fish target organ tissues (*Tilapia mossambique* and *Cynoscion xanthulus*) from the Salton Sea and compare analyte concentrations found in sediments and fish with sediment quality criteria such as Probable Effect Levels (PEL), Effect Range-Low (ERL), Effect Range-Median (ERM) and fish Threshold Effect Levels (TEL) to determine whether resident fish or wildlife may be adversely affected.

Methods and Materials

Study area and sampling

The Salton Sea is located 120 miles northeast of San Diego in Imperial County, CA. It is 35 miles long and 15 miles wide with 115 miles of shoreline, and its deepest part only about 50 feet (Figure 1).

Sediment samples were taken from 6 sampling sites located in the middle; M1 (33°20’, 115°51’), north; N1 (33°25’, 115°57’) and N2 (33°30’, 116°03’), and south; S1 (33°15’, 115°42’), S2 (33°13.75’, 115°37.5’), S3 (33°10’, 115°45’) of the Sea during May 2000 and May 2001 using a ponar grab sampler. Top 10 cm were taken, single samples were collected from each site.

Fish samples were collected from the southern part of the Sea, (near the Southern input of the Alamo River, sampling station S2 (33°13.75’, 115°37.5’) using gill-netting during May 2001. Two species were collected for analyses: Tilapia (*Tilapia mossambique*) – 9 samples, 2 – females, 7 –

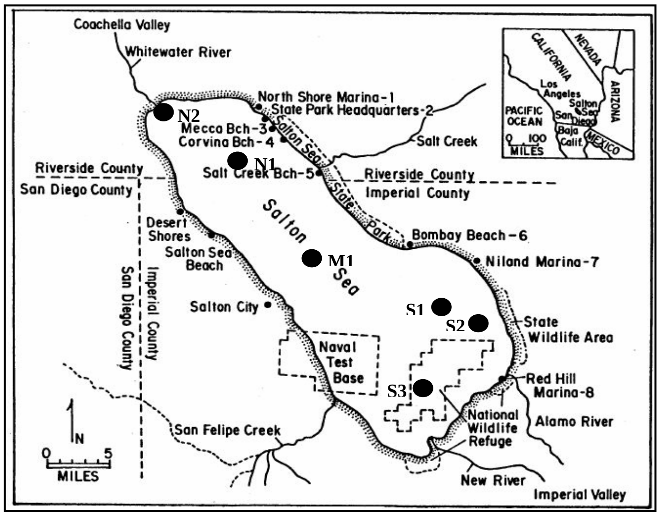

Fig.1. Diagramatic view of the Salton Sea

● - sampling stations

Sediments
May 2000- May 2001
N2, N1, M1, S1, S2, S3

Fish tissue
May 2001 S2 (south)

males, and Orange mouth Corvina (*Cynoscion xanthulu*) – 6 samples, all males. Tilapia are the most abundant species in the Salton Sea and were shown to have higher levels of DDT and DDE than Corvina in earlier studies[4]. Four organs from each fish were analyzed: muscle, liver, gonads and gills.

Chemical Analysis

All samples were analyzed for 12 chlorinated pesticides and 55 polychlorinated biphenyl (PCB) congeners. Sediments were separated from pore water using Buchner funnels, then extracted with acetone and hexane. Extracts were passed through Florisil cartridges (Superclean ENVI-Florisil SPE tubes 6 ml, 1 g) according to EPA method 3620B[5]. Fish tissues were extracted with hexane using an ultrasonic disruptor according EPA method 3550B[5] and cleaned up with Florisil micro-columns (6 g). Sample extracts were analyzed using a Hewlett Packard HP-6890 gas chromatograph, equipped with an electron Capture Detector (ECD) and a DB-5MS fused silica capillary column (60 m x 0.32 mm x 0.25 µm). A confirmation column of different polarity from the quantitation column (DB-35) was used to verify chemical identity. Analyte recoveries were determined by using sediments and fish tissues spiked with pesticides and PCBs. The pesticide recoveries were 70-101% in sediments and 70-108% in fish tissues with relative standard deviations (RSDs) of 5-10% and 5-17% for sediments and fish respectively. For PCBs, the recoveries were 83-108% in sediments and 65-99% in fish tissues with RSDs of 6-17% and 8-16%. The method detection limit (MDL) ranged from 0.1-0.23 µg/kg and 0.1-0.21 µg/kg for pesticides and from 0.1-0.18 µg/kg and 0.1-0.3 µg/kg for PCBs in sediments and fish respectively.

Results and Discussion

The most commonly detected organochlorine pesticides in sediments, which also occurred in the greatest concentrations, were lindane, chlorothalonil, dieldrin, heptachlor and isomers/derivatives of DDT. ΣDDT average concentrations ranged from 10.3 to 40.2 ng/g dry weight. ppDDE was the most abundant of the DDT derivatives, constituting 60 - 100% of the ΣDDT at specific sites. Sampling stations located in the middle (M1) and south (S1) of the Sea had the highest concentrations of ΣDDT in 2000, whereas lower concentrations of ΣDDT were observed in all stations in 2001. In northern stations (N1), there were only DDT and DDD isomers observed in

2001, but no DDEs. The fact of not detecting DDE isomers, which are one of the terminal metabolites in DDT degradation (DDT→DDD→DDE), could indicate relatively recent DDT exposure. Another argument supporting this possibility is the DDT/DDD ratio, which was more than 1 for this sampling site, indicating recent DDT input at this location.

Sediment concentrations of lindane, dieldrin, DDE isomers and total PCBs, found in the Salton Sea, exceeded Probable Effect Levels (PEL), established for sediments quality in freshwater[6]. ppDDE, ΣDDT and total PCBs exceeded Effect Range-Median (ERM) values, developed for marine and estuarine sediments in 25, 85 and 63% of cases, respectively, indicating the potential of frequently occurring adverse effects[7].

DDT and its metabolites were also detected in Tilapia (*Oreochromis mossambicus*) and Orangemouth Corvina (*Cynoscion xanthulus*) ΣDDT concentrations ranged from 6.1 to 316.3 ng/g in Corvina and from 6.8 to 216.3 ng/g in Tilapia samples. For tissues of both species DDTs showed a high frequency of occurrence 96-100%. The most abundant both by weight and frequency of occurrence was ppDDE. DDD, as well as isomers of DDT. ΣDDT residues were observed in greatest amounts in livers: (129±112 ng/g), (77 ± 70 ng/g); followed by gonads: (50±25 ng/g), (70±50 ng/g); gills: (31±17 ng/g), (40±27 ng/g); and muscles: (18±11 ng/g), (15±7 ng/g) for Corvina and Tilapia, respectively.

DDT concentrations detected in both Corvina and Tilapia liver exceeded Threshold effect Levels (TELs) established for shrimps in saltwater – 40-190 ng/g[8]. ∑DDT concentrations detected in fish tissues were higher than threshold concentrations for the protection of wildlife consumers of aquatic biota (14 ng/g)[9]. DDE concentrations in fish muscles tissues were above the 50 ng/g concentration threshold for the protection of predatory birds[10]. Therefore, avifauna may still be at risk due to high DDE contamination because of their high fish consumption rates and consequent potential of these toxicants to bioaccumulate.

Previous investigators[4] showed that fish collected from the Salton Sea had body burdens with a proportional composition of 70% DDE, 20% DDD, and 10% DDT. In our study the proportional compositions were 50% DDE, 25% DDD, and 25% DDT for Corvina and 65% DDE, 10% DDD, and 25% DDT for Tilapia. The reduction of the DDE proportion coupled with the enhancement of DDT up to 25% in both species could indicate relatively recent DDT exposure. Also, DDT/DDD ratios in both species was greater than 1, indicating recent exposure. Therefore, further studies of the Salton Sea ecosystem are necessary to determine whether DDT input is continual to this waterway.

For other organochlorine pesticides, lindane, dieldrin and endrin were also observed in Tilapia and Corvina tissues, with the highest concentrations observed in liver. Endrin concentrations in Corvina liver exceeded Threshold Effect Levels (TELs), established for invertebrates (grass shrimps) 50 ng/g whole body[8]. Heptachlor dieldrin, endrin and hexachlorobenzene were found in all fish samples analyzed, but did not exceed TELs.

Conclusions

This study determined pesticide and PCB concentrations in sediments and fish tissues from the Salton Sea and evaluated the relative ecological risk of these toxicants in this waterway. DDT pesticides were observed in elevated concentrations both in sediments and fish tissues, and the DDT/DDD ratio indicated recent exposure in sediments of the northern Sea area in 2001 as well as Tilapia and Corvina tissues. Therefore, additional studies should be carried out to determine the source of recent DDT input. Lindane, dieldrin, ∑DDE and total PCB concentrations detected in sediments exceeded PECs established for freshwater ecosystems, and ppDDE and total PCB concentrations were higher than ERM values developed for marine and estuarine sediments. In fish liver, concentrations of endrin and ∑DDT exceeded TELs established for invertebrates, and exceeded thresholds for predatory birds. Detection of contaminants in concentrations higher than established quality criteria in sediments and fish tissues indicate potential stress to Salton Sea biota.

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References

1. Jehl, J. 1996. Mass mortality vents of eared grebes in North America. *Journal of Field Ornithology.* 67: 471-476.
2. Kaiser, J. 1999. Battle over a dying sea. *Science*. 284: 28-30.
3. Olivero, J., Navas, V., Perez, A., Solano, B., Acosta, I., Arguello, E., Salas, R. 1997. Mercury levels in muscle of some fish species from the Dique Channel, Colombia. *Bulletin of Environmental Contamination and Toxicology.* 58:865-870.
4. Setmire, J.G., Schroeder, R.A., Densmore, J.N., Goodbred, S.L., Audet, D.J., Radke, W.R. 1993. Detailed study of water quality, bottom sediment, and biota associated with irrigation drainage in the Salton Sea area, California, 1988-90. U.S. Geological Survey Water Resources Investigations Report 93-4014, 102 pp.
5. United States Environmental Protection Agency. 1996. Test methods for evaluating solid waste, physical/chemical methods, SW-846, 3rd edition, proposed update II. Washington, DC, USA. Office of Solid Waste and Emergency Response.
6. MacDonald D.D., Ingersoll G.G., Berger T.A. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology*, 39, 20-31.
7. Long, ER, MacDonald DD, Smith SL,Calder FD. 1995. Incidence of Adverse Biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management.* 19:1, 81-97.
8. Jarvinen, A. W., Ankley, G.T. 1999. Linkage of Effects for Tissue Residues: Development of a Comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals, Pensacola FL: Society of Environmental Toxicology and Chemistry (SETAC), 364 pp.
9. Environment Canada. 1997. Canadian tissue residue guidelines for DDT for the protection of wildlife consumers of aquatic biota. Final unpublished draft. Environment Canada, Science Policy and Environmental Quality Branch, Guidelines and Standards Division, Hull, Quebec, CN. 278 p.
10. National Academy of Sciences and National Academy of Engineering, 1973. Water quality criteria, United States Environmental Protection Agency Report, EPA R3-73-033.