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Persistence of pesticides in water, sediment and fish from fish farms in Kolleru Lake, India

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Abstract: Kolleru Lake is a freshwater lake in south-eastern India with a high potential for aquaculture. It is located between 61°32′ and 61°47′N latitude and 81°15′ and 81°27′E longitude. Various chemicals such as pesticides are used to control diseases and ectoparasites in intensive aquaculture farms in India. The main aim of this paper was to determine selected pesticides in water, sediment and fish from 12 fish farms located in Kolleru Lake in order to assess the quality of fish for human consumption and to improve the further risk assessment and management of such chemicals in aquaculture and also to evaluate the impact of aquaculture chemicals on the Kolleru Lake environment. The chemicals used in intensive aquaculture farms were documented. Water, sediment and fish samples were collected from the fish farms during the production period and analysed for the pesticides *α*-BHC, *γ*-BHC, malathion, chloropyrifos, isodrin, endosulfan, dieldrin and *p,p′*-DDT using gas chromatography.

Keywords: fish farms; water; sediment; fish; pesticides

INTRODUCTION

The aquaculture industry is expanding in many regions of the world, including India, to produce wholesome food for human consumption. India has a long tradition of freshwater fish culture in lakes, rivers, reservoirs, ponds, estuaries and coastal waters. Kolleru Lake is located in south-eastern India (see Fig 1). The total area of the lake basin is $4763\,km^2$ and it is connected to the sea through the Upputeru River, which is the only outlet for the lake. Kolleru Lake is an important source of drinking water, agriculture and aquaculture in the region. Aquaculture effluents and agriculture run-off directly enter Kolleru Lake. A mushrooming of aquaculture farms has occurred in the Kolleru Lake region. Suitable species of fish for aquaculture in India are C*atla catla* (catla), *Labeo rohitoe* (rohu), C*irrhinus mrigala* (mrigala), *Labeo calbasu* (kalbose), *Eternopharvngodon idella* (grass carp), *Cyprinus carpio* (common carp) and *Hypotithalmidhthys molitrixl* (silver carp).

In order to control excessive algal growth and potentially disastrous phytoplankton blooms, the use

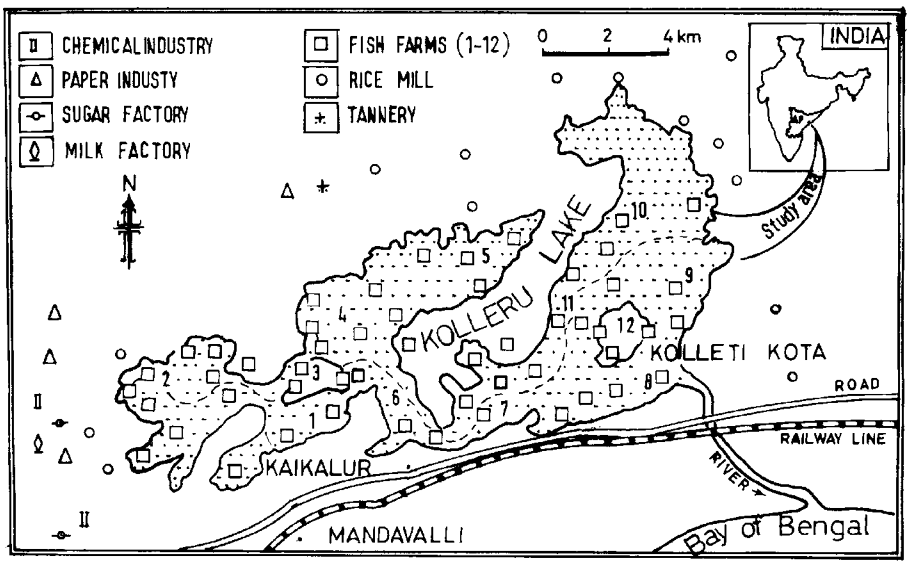

Figure 1. Locations of fish farms in the Kolleru Lake region.

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of pesticides and algicides in aquaculture practices[1] is essential to profitable production of fish. Adverse ecological effects from the use of pesticides, the suspected link with birth defects in birds, fish and rats, and numerous other consequences from the use of agricultural chemicals have effectively motivated public concern. The possible effects of aquaculture chemicals on the quality of the water, sediment and fish in fish farms have been discussed by several authors,[2–4] as have the effects on humans who consume fish contaminated with pesticides and the impact on the environment.[5–8]

Keeping in view all the above points, the author has determined the pesticide levels in water, sediment and fish from 12 fish farms in order to assess the quality of fish for human consumption and to improve the further risk assessment and management of such chemicals in aquaculture and also to evaluate the impact of aquaculture chemicals on the Kolleru Lake environment.

EXPERIMENTAL

Solvents and chemicals

All solvents were glass distilled and made free of interfering residues by following the purification procedure[9] to obtain gas chromatographic (GC) grade solvents. Florisil, anhydrous sodium sulphate and glass wool were pre-extracted with hexane/acetone (2:1 v/v). Florisil was heated at 300 °C overnight, while both anhydrous sodium sulphate and glass wool were heated at 100 °C. Pesticide standards and florisil (60–80 mesh) were purchased from Aldrich Chemical Co, Ltd (USA). All glassware was rinsed with acetone and hexane before use.

Sampling

Twelve intensive freshwater fish farms in the Kolleru Lake were selected for the study (Fig 1). The average area of each fish farm is about 6 ha. The maximum water depth maintained in the ponds is 1.5 m. The range of stocking density is 28–40 fish per m^2. The water source for aquaculture is Kolleru Lake. The aquaculture effluents are directly discharged into the lake. The ambient air temperature in the study area ranged between 19.4 and 38.1 °C. The surface water temperature of the ponds closely followed the same trend as the ambient air temperature, often fluctuating from 23 to 31 °C. Water, sediment and fish samples were collected from the fish farms in glass bottles. Each farm was sampled six times during the production year. Each water and sediment sample was a composite of subsamples collected from at least five locations in the farm. Twenty-five fish samples were from each farm and analysed for pesticides. Fish of approximately the same age and weight were selected for analysis and dissected.

Extraction

Hexane/acetone (2:1 v/v) was used for the extraction of pesticides in water, sediment and fish samples from the fish farms. The samples were analysed for pesticides according to standard methods.[10–15]

Water samples were extracted three times with 100 ml of hexane/acetone (2:1 v/v). The extract was dried over sodium sulphate and concentrated to about 3 ml by rotary flash evaporation.

Sediment samples were well mixed on a pre-cleaned aluminium plate and air-dried at ambient temperature. A 100 g sample of air-dried sediment was weighed accurately into a 250 ml pre-washed conical flask for extraction and 150 ml of hexane/acetone mixture (2:1 v/v) was added. The extraction was carried out for 1 h in a horizontal shaker bath at gentle speed to avoid spillage. The extract was filtered by suction through Whatman No 1 filter paper in a Buchner funnel. The extract was dried over anhydrous sodium sulphate, concentrated to about 3 ml by rotary flash evaporation and stored in a refrigerator until further processing.

Fish were dissected into different tissues. About 5 g of muscle tissue was blended with 10 g of anhydrous sodium sulphate (pre-extracted in a Soxhlet column with gas chromatographic grade hexane) to get a free-flowing powder. This powder was extracted with hexane/acetone (2:1 v/v) at $2\,ml\,g^{-1}$ powder. Soft tissue such as liver was homogenised in a tissue homogeniser with the minimum quantity of all-glass doubly distilled water. The homogenised tissue was extracted with hexane/acetone (2:1 v/v) at $2\,ml\,g^{-1}$ tissue. When only a very small quantity of tissue was available, a minimum of 6 ml of extraction solvent was used. The extraction was carried out for 1 h in a horizontal shaker bath at gentle speed to avoid spillage. The extract was filtered by suction through Whatman No 1 filter paper in a Buchner funnel. The extract was dried over anhydrous sodium sulphate, concentrated to about 3 ml by rotary flash evaporation and stored in a refrigerator until further processing.

Clean-up

The water, sediment and fish extracts, concentrated to about 3 ml, were cleaned on a florisil column to remove any co-extracted matter which would interfere with the end determination. A 4 inch florisil column (about 15 g of deactivated florisil with water 2% v/w) was bottomed and topped with 1 inch anhydrous sodium sulphate. The extract was run into the column and eluted with 100 ml of hexane followed by successive grades of increasing polarity comprising hexane and diethyl ether. α-BHC was eluted with hexane. γ-BHC, endosulfan, malathion, chlorpyrifos, dieldrin, isodrin and p,p'-DDT were eluted with 7% diethyl ether in hexane and further concentrated to 1 ml by rotary flash evaporation. No identifiable pesticide compounds were eluted with 16% diethyl ether in hexane.

Analysis

All concentrated samples were analysed for pesticides

Table 1. Chemical and biological products used in freshwater fish farms ($n=12$) in the Kollern Lake region

Use	*Chemical group*
1. Thermapeutants and disinfectants	Iodine Formalin Malachite green Butox
2. Soil and water treatment	Lime Salt
3. Plankton growth promoters	NPK Urea DAP Superphosphate Potash Chicken dung
4. Pesticides and algicides	Malathion Endosulfan Dimethoate Monocrotophos Chloropyrifos
5. Feed	Cottonseed powder Rice bran Oil-cake (groundnut) Snail meat

on a Chemito model 3865 gas chromatograph coupled with a Ni electron capture detector and an Oracle integrator. The instrument was equipped with an SE-30 glass column (1.22 m × 0.064 mm id) packed with 1.95% SE 2401 on 100–120 mesh particles. The analysis was performed under the following conditions. The carrier gas was nitrogen at a flow rate of $32\,\text{ml}\,\text{min}^{-1}$. The injection port and detector temperatures were 200 and 300 °C respectively. The oven was operated isothermally at 180 °C. The concentrations of pesticide residues in water, sediment and fish samples were determined by comparing the peak area of the sample against appropriate standards.

RESULTS

The inputs of chemical and biological products in the freshwater fish farms are presented in Table 1. The range of pesticides in water and sediment from the fish farms is presented in Table 2. The range of pesticides in fish tissues is presented in Table 3. Fig 2 shows the standard chromatogram for the selected pesticides. Figs 3–5 show typical chromatograms for water, sediment and fish respectively.

DISCUSSION

In general, water, sediment and fish samples from the selected freshwater fish farms were contaminated with pesticides. The results of this study indicate that the pesticide concentrations in fish farms decrease in the order sediment > fish > water. The maximum concentrations of pesticides were observed in fish farms 1 and 5–8. This may be due to the intensive use of pesticides in these fish farms and also to the fact that these farms are located near agricultural fields. Pesticides such as α-BHC, γ-BHC, isodrine, dieldrin and *p,p'*-DDT were

Table 2. Range of pesticides in water and sediment from fish farms[a]

		α-BHC	*γ-BHC*	*Malathion*	*Chloropyrifos*	*Isodrin*	*Indosulfan*	*Dieldrin*	*p,p'-DDT*
Farm 1	Water	BDL–152	BDL–58.2	BDL–95.2	BDL–116	BDL	BDL–125	BDL	BDL–86.5
	Sediment	1.2–125	BDL–95.6	BDL–81.5	7.6–102	BDL	BDL–139	BDL	BDL–127
Farm 2	Water	BDL–108	BDL–83.9	BDL–128.6	BDL–81.2	BDL	BDL–48.6	BDL–12.9	BDL–53.7
	Sediment	2.7–146	BDL–65.7	BDL–178	BDL–154	BDL	BDL–76.9	BDL–21.6	BDL–98.2
Farm 3	Water	5.4–85.8	BDL–47.2	BDL–161.2	BDL–59.5	BDL	BDL–57.8	BDL	BDL–32.4
	Sediment	BDL–107.5	BDL–83.8	BDL–127.5	BDL–81.3	BDL	BDL–71.2	BDL	BDL–56.9
Farm 4	Water	BDL–69.3	BDL–37.9	BDL–102.5	BDL–119	BDL	BDL–29.5	BDL	BDL–49.8
	Sediment	BDL–112.8	BDL–98.7	BDL–149	BDL–91.2	BDL	BDL–83.6	BDL	BDL–75.7
Farm 5	Water	BDL–91.7	BDL–58.2	BDL–86.3	BDL–128.6	BDL	BDL–62.7	BDL	BDL–112.6
	Sediment	BDL–102	BDL–89.4	BDL–108	BDL–87.5	BDL	BDL–114	BDL	BDL–57.3
Farm 6	Water	BDL–137.2	3.4–97.5	BDL–58.1	BDL–89.2	BDL	BDL–154	BDL	BDL–57.1
	Sediment	BDL–84.7	BDL–118.3	BDL–87.5	BDL–61.9	BDL	BDL–95.2	BDL	BDL–89.6
Farm 7	Water	BDL–108.7	BDL–72.9	BDL–35.4	BDL–44.5	BDL	BDL–91.8	BDL	BDL–75.4
	Sediment	BDL–96.5	BDL–183.4	BDL–94.2	BDL–128	BDL	BDL–112	BDL	BDL–54.2
Farm 8	Water	BDL–98.5	BDL–64.7	BDL–78.2	BDL–38.5	BDL	BDL–27.5	BDL	BDL–58.9
	Sediment	BDL–156.2	BDL–112.5	BDL–129.6	BDL–81.2	BDL	BDL–63.4	BDL	BDL–98.2
Farm 9	Water	BDL–96.8	BDL–81.2	BDL–131	BDL–174	BDL	BDL–129	BDL	BDL–83.6
	Sediment	BDL–115.2	BDL–126.8	BDL–74.8	BDL–87.5	BDL	BDL–97.6	BDL	BDL–108.5
Farm 10	Water	BDL–78.4	BDL–46.7	BDL–93.6	BDL–112	BDL	BDL–78.2	BDL	BDL–108.9
	Sediment	BDL–95.8	BDL–103.9	BDL–123	BDL–95.6	BDL	BDL–123.5	BDL	BDL–145
Farm 11	Water	BDL–104	BDL–73.5	BDL–51.5	BDL–28	BDL	BDL–41.6	BDL	BDL–61.2
	Sediment	BDL–129	BDL–108	BDL–87.8	BDL–59.2	BDL	BDL–91.7	BDL	BDL–86.4
Farm 12	Water	BDL–84.1	BDL–38.7	BDL–22.6	BDL–55.3	BDL	BDL–64.2	BDL	BDL–39.8
	Sediment	BDL–109	BDL–75.6	BDL–84.2	BDL–101	BDL	BDL–97.5	BDL	BDL–73.5

[a] Concentrations of pesticides are expressed in $\text{ng}\,\text{l}^{-1}$ for water and $\mu\text{g}\,\text{g}^{-1}$ for sediment (dry weight). BDL, below detectable limit.

Table 3. Range of pesticides in tissues of fish from fish farms ($\mu g\,g^{-1}$ wet weight)

		α-BHC	*γ-BHC*	*Malathion*	*Chloropyrifos*	*Isodrin*	*Endosulfan*	*Dieldrin*	p,p′-*DDT*
Farm 1	Muscle	BDL–5.6	BDL–3.8	BDL–6.5	BDL–4.7	BDL	BDL–2.8	BDL	BDL–10.7
	Gills	1.5–28.9	1.9–21.2	BDL–14.6	1.2–28.6	BDL	BDL–10.8	BDL	BDL–25.5
	Liver	2.7–50.4	3.6–68.9	BDL–23.9	2.8–3.8	BDL	BDL–26.4	BDL	1.2–51.2
Farm 2	Muscle	BDL–3.4	BDL–8.9	BDL–2.5	BDL–8.9	BDL	BDL–4.7	BDL	BDL–5.3
	Gills	BDL–2.8	BDL–14.6	BDL–6.2	BDL–16.3	BDL	BDL–18.6	BDL	BDL–28.7
	Liver	BDL–18.3	BDL–43.8	BDL–15.8	BDL–34.7	BDL	BDL–39.5	BDL	BDL–42.5
Farm 3	Muscle	BDL–10.7	BDL–5.1	BDL–1.6	BDL–6.8	BDL	BDL–5.1	BDL	BDL–4.2
	Gills	1.2–23.5	2.3–38.7	BDL–5.9	BDL–21.5	BDL	BDL–11.8	BDL	BDL–12.5
	Liver	2.5–37.4	3.6–56.4	BDL–21.3	BDL–38.2	BDL	BDL–27.3	BDL	BDL–31.8
Farm 4	Muscle	BDL–16.3	BDL–21.5	BDL–5.4	BDL–9.6	BDL	BDL–10.1	BDL	BDL–8.7
	Gills	2.2–28.7	4.7–36.9	BDL–22.8	BDL–18.9	BDL–1.7	BDL–23.9	BDL	BDL–17.3
	Liver	4.8–54.6	5.8–68.7	BDL–45.3	BDL–34.2	BDL–2.9	BDL–48.3	BDL	BDL–34.6
Farm 5	Muscle	BDL–9.6	BDL–12.5	BDL–3.8	BDL–2.8	BDL	BDL–5.1	BDL	BDL
	Gills	BDL–25.4	BDL–33.7	BDL–12.3	BDL–12.6	BDL	BDL–21.2	BDL–3.5	BDL
	Liver	BDL–49.2	BDL–58.2	BDL–21.7	BDL–59.3	BDL	BDL–29.7	BDL–5.1	BDL
Farm 6	Muscle	BDL–5.2	BDL–8.9	BDL–3.6	BDL–5.4	BDL	BDL–8.9	BDL	BDL–4.5
	Gills	BDL–17.4	BDL–24.8	BDL–5.4	BDL–18.6	BDL	BDL–16.4	BDL	BDL–10.2
	Liver	BDL–25.8	BDL–41.6	BDL–16.1	BDL–37.8	BDL	BDL–35.7	BDL	BDL–28.7
Farm 7	Muscle	BDL–12.7	BDL–21.5	BDL–2.1	BDL–12.6	BDL	BDL–2.6	BDL	BDL–1.8
	Gills	BDL–19.5	BDL–36.2	BDL–6.8	BDL–23.2	BDL	BDL–13.2	BDL	BDL–3.5
	Liver	BDL–44.3	BDL–67.4	BDL–14.5	BDL–47.5	BDL	BDL–31.4	BDL	BDL–7.9
Farm 8	Muscle	BDL–2.5	BDL–7.8	BDL–4.8	BDL–1.8	BDL	BDL–8.2	BDL	BDL–2.9
	Gills	BDL–11.8	BDL–18.2	BDL–17.2	BDL–21.6	BDL	BDL–22.4	BDL	BDL–10.8
	Liver	BDL–27.1	BDL–41.7	BDL–38.4	BDL–43.4	BDL	BDL–47.6	BDL	BDL–25.4
Farm 9	Muscle	BDL–18.4	BDL–26.2	BDL–1.7	BDL–8.9	BDL	BDL–6.4	BDL	BDL–1.8
	Gills	BDL–28.7	BDL–37.4	BDL–10.6	BDL–14.6	BDL	BDL–17.5	BDL	BDL–7.2
	Liver	BDL–53.2	BDL–69.5	BDL–23.4	BDL–293	BDL	BDL–45.6	BDL	BDL–16.5
Farm 10	Muscle	BDL–5.2	BDL–9.3	BDL–14.8	BDL–21.6	BDL	BDL–12.4	BDL	BDL–5.2
	Gills	BDL–12.8	BDL–18.4	BDL–28.6	BDL–38.5	BDL	BDL–24.9	BDL	BDL–16.5
	Liver	BDL–28.5	BDL–25.8	BDL–41.9	BDL–59.2	BDL	BDL–42.1	BDL	BDL–28.9
Farm 11	Muscle	BDL–14.6	BDL–22.5	BDL–2.8	BDL–6.5	BDL	BDL–5.2	BDL	BDL
	Gills	BDL–25.2	BDL–31.9	BDL–7.2	BDL–18.2	BDL	BDL–16.6	BDL	BDL
	Liver	BDL–41.7	BDL–58.2	BDL–19.5	BDL–35.6	BDL	BDL–27.5	BDL	BDL
Farm 12	Muscle	BDL–5.8	BDL–10.7	BDL–8.6	BDL–2.8	BDL	BDL–16.2	BDL	BDL–2.6
	Gills	BDL–13.7	BDL–21.2	BDL–15.4	BDL–14.6	BDL	BDL–23.8	BDL	BDL–14.8
	Liver	BDL–263	BDL–37.5	BDL–28.9	BDL–32.5	BDL	BDL–36.7	BDL	BDL–24.1

BDL, below detectable limit.

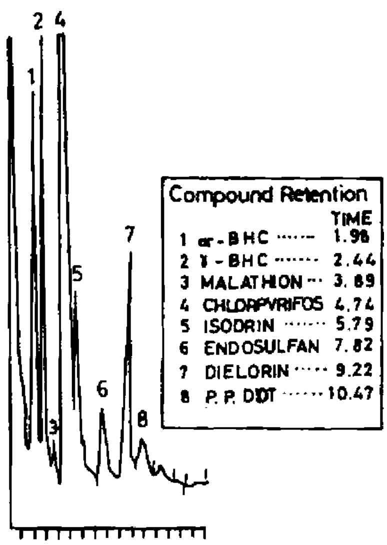

Figure 2. Standard chromatogram for selected pesticides.

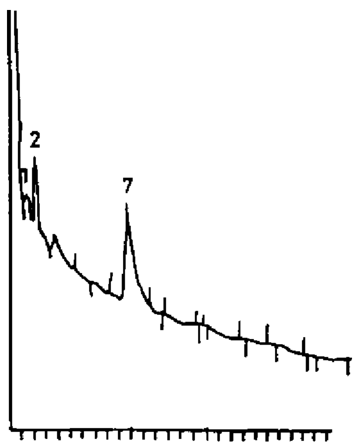

Figure 3. Typical chromatogram for water (see Fig 2 legend).

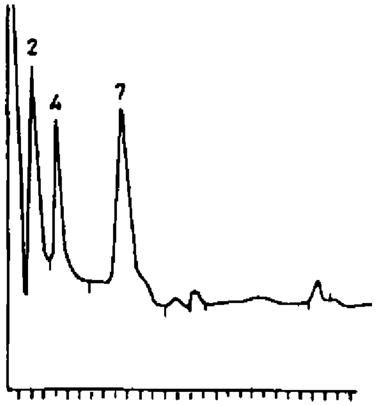

Figure 4. Typical chromatogram for sediment (see Fig 2 legend).

found in the fish farms even though they are not used in aquaculture farms. The concentrations of isodrin in water, sediment and fish from the fish farms were below detectable limits. The contamination of these pesticides in fish farms can be attributed to the extensive use of pesticides in agricultural fields in the lake basin.[10–12] The extensive use of pesticides in aquaculture farms may control diseases and ectoparasites, but the pesticides contaminate the sediment and water and finally these pesticides are accumulated by fish. Pesticides in water and sediment from fish farms may produce various effects on fish, such as mass mortality, chronic changes in behaviour, low survival rate and morphological and physiological changes in different organ systems.[16–19] The concentrations of pesticides in fish were compared with standards for human consumption.[20] The standard pesticide levels in fish on a wet weight basis are 0.5 mg kg^{-1} for α-BHC and γ-BHC, 1.0 mg kg^{-1} for malathion, chloropyrifos, dieldrin and isodrin, 2.0 mg kg^{-1} for endosulfan and 5.0 mg kg^{-1} for *p,p′*-DDT. Pesticides have cumulative effects on the human body and lead to several diseases, ranging from chronic common cough and cold and bronchitis to cancer of the skin, eye, kidney and prostate gland.[21–23] From a food hygiene viewpoint the pesticide levels in fish from the selected fish farms were higher than the standards.[20] As is evident from the data, the concentrations of pesticides found in fish tissues were highest in the liver, followed by gills and muscle. These results support the availability of pesticides in fish farm sediment and water. Fish contaminated with pesticides may not be consumed as food.

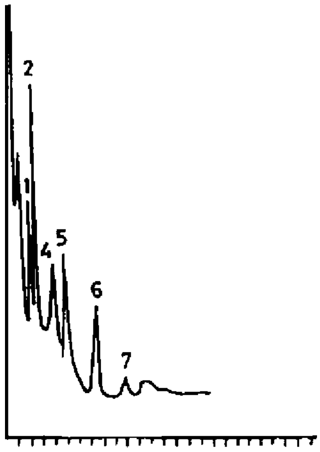

Figure 5. Typical chromatogram for fish (see Fig 2 legend).

High deposition of pesticides in sediment can inhibit the microbiological activity in the sediment below fish farms, thereby affecting the rate of degradation of organic matter.[24,25] This in turn leads to the anaerobic generation of hydrogen sulphide, carbon dioxide and methane. These effects are well recognised because they affect both fish farms and the environment. The concentration of pesticides found in freshwater fish farms in Kolleru Lake can be attributed to the indiscriminate use of pesticides in intensive fish farms to control diseases and ectoparasites and to agriculture run-off into the fish farms from surrounding agricultural fields and also from the source water. Aquaculture effluents are directly discharged into Kolleru Lake in addition to the agriculture run-off, which affects the quality of the lake water. Kolleru Lake is the source water for aquaculture farms in the lake region. Water, sediment and fish from Kolleru Lake were contaminated with pesticides.[10–12] Therefore it is clear that excessive use of pesticides in fish farms and source water have an important influence upon the pesticide pollution status of freshwater fish farms and also the trophic status of Kolleru Lake.

CONCLUSIONS

The results show that pesticides were found in water, sediment and fish from freshwater fish farms in Kolleru Lake in India. The input of chemicals such as pesticides in intensive aquaculture may cause the accumulation of pesticides in fish tissues from the sediment and water from fish farms. The pesticide levels in fish are higher than the standards for human consumption. The sediment acts as a sink for pesticides used in aquaculture farms. High concentrations of these pesticides not only affect the fish but also humans in the long run. The fish were also found to be suffering from various types of disease owing to water pollution in the aquaculture farms. The impact of aquaculture on the lake ecosystem is an increased concentration of pesticides. The lake water quality, flora and fauna are deteriorating daily owing to aquaculture practices in the lake region, besides other activities. Most of the agricultural land in the lake region is being converted into aquaculture farms. The encroachment of lake land for aquaculture practices causes a deterioration of lake water, obstructs its free flow and has detrimental effects on the aquatic life. Based on these impacts of aquaculture, the authorities should not allow aquaculture practices in the lake region below +5 contour level. The authorities should give necessary guidance to farmers about the rational use of chemicals such as pesticides for better management of aquaculture and also monitor the chemicals used in fish farms in order to produce a suitable quality of fish for human consumption and to protect the ecosystem of the lake.

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