GIS APPLICATION FOR ANALYSES AND EVALUATION OF RESIDUAL PESTICIDES IN A COASTAL LAGOON

Aysegul Tanik[1], Dursun Z. Seker[2], Alpaslan Ekdal[1], Ali Erturk[1] and Melike Gurel[1]

[1]ITU, Istanbul Technical University, Faculty of Civil Engineering, Dpt. of Environmental Eng'g, 80626, Maslak, Istanbul-Turkey
tanika@itu.edu.tr, ekdala@itu.edu.tr, aerturk@ins.itu.edu.tr, mgurel@ins.itu.edu.tr
[2]ITU, Istanbul Technical University, Faculty of Civil Engineering, Dpt. of Geodesy and Photogrammetry Eng'g, 80626, Maslak, Istanbul-Turkey
dzseker@ins.itu.edu.tr

Visualization and analyses of both land and water quality data through geographical information systems (GIS) aid to better understand the prevailing situation especially in sensitive coastal areas. Such attempts will form a basis to modeling studies and establishment of appropriate management strategies. This paper focuses on visualization and analyses of four residual pesticides, namely endosulfan, diazinon, dichlorvos and deltamethrin, in a lagoon system in Turkey by utilizing GIS techniques. The seasonal data obtained from two different depths at 16-selected sampling stations are mapped out by using ArcView 3.2. The queries are based on both national tolerance limits depicted for three of the pesticides and EU Directives for pesticides in drinking water. Similar studies using new computer technologies enhance and promote researches on ecological modeling and sustainable management.

1. INTRODUCTION

Increasing controls and legislation on environmental contamination has been accelerated since 1980's by growing public awareness on environmental issues. In particular, attention has been focused on the use/misuse of modern agrochemicals, which are specifically manufactured for crop protection and enhancement, and on the potential for contamination of soil and water environments. Pesticide losses from application areas and contamination of non-target sites represent a monetary loss to the farmer as well as a threat to the environment. Thus, careful management of pesticides in order to avoid environmental contamination is desired by both farmers and by the public. Regarding the soil and aquatic environment, it is necessary to investigate the behavior and fate of a pesticide in both soil and aquatic systems, in particular how it is distributed and how it degrades. This paper tries to enlighten those working in the field of environmental engineering especially on agricultural diffuse pollutants by visualizing and analyzing the seasonal water residue data of four pesticides measured in a selected lagoon media through the aid of geographical information system (GIS). It is for sure that one of the modern technologies processing environmental information is GIS. When such environmentally important issues are aided by the application of GIS techniques, current findings will be evaluated and assessment of probable changes in any of the water data will be realized in a short period of time, which will allow the related scientists to interfere or to take immediate precautions against further deterioration. In literature, many recent publications on environmental modeling achieved by application of GIS exist [*Fedra*, 1993; *Burrough and Mc Donell*, 1996; *Masuda et al.,*2000; *Nemeth et al.*, 2002; *Matsui et al.*, 2002]. Establishment of a flexible GIS project for pesticide management will also give a chance to re-run the program and to renew the analyses in case of new data obtained. This study will form an example to GIS application on the distribution and visualization of agricultural diffuse pollutants on receiving water.

The target area of concern where water residue data had already been obtained is the watershed of a coastal lagoon (Dalyan lagoon) at the southwest of Turkey with an area of 130 km^2, joining the Mediterranean Sea. Part of the region has been declared as a 'Special Protection Area' due to its natural resources and ecological characteristics, agricultural production, fishery and tourism activities. Rarely found caretta-caretta sea turtles utilize the area as their nesting and breeding sites. Such sensitive and vulnerable watersheds must be protected through an integrated approach leading to sustainable management. The agricultural activities are similar to Mediterranean countries based on polyculture basically cotton, citrus fruits, wheat, corn, pea and horticulture. Almost 23% of the land is spared for intensive agriculture. Approximately 40 pesticides were used which were further evaluated and classified according to their physical, chemical and toxicological characteristics [*Guvensoy*, 2000]. Under the light of a detailed survey, the pesticides were grouped according to their probable transportation pathways on soil -those likely to appear in run-off, those likely appear in groundwater and those in transient condition-. Out of the 40 pesticides only 6 of them were selected for the residue analyses to discuss their water quality impacts. The six pesticides were selected so as to represent each group. It was then that a pair of water samples from each of the 16 monitoring stations were seasonally collected for a year long along the lagoon channel, one from the surface and the other from the bottom layer for observing the residual pesticides [*Tanik et al.*, 2002].

In this study, the residual pesticide data will be visualized and analyzed through GIS. Out of 6 pesticides only 4 of them, namely deltamethrin, diazinon, endosulfan and dichlorvos appeared in the water environment. Visualization of the current data belonging to all seasons of the year will enable the interested scientists to better understand the trend of pesticide distribution in water, and analyses will be handled through matching the data with both the National Standards and the European Standards for each of the four pesticides. Such an approach will present the current effect of pesticide application on land, which will further aid to take precautions in future.

Most of the management and modeling studies require the integration of geographical information systems (GIS) as such, various scenarios for future can easily be applied besides presenting the current situation. The carried out activities within the framework of ecological modeling of Dalyan Lagoon involve considerable efforts in data collection and creation of data base related to climatic conditions, soil characteristics, administrative boundaries, land use and topographic data in the form of coverage's [*Seker et al.*, 2002a]. The ongoing activities are focused mainly on the completion of GIS data on water quality. The queries on residual pesticides will be accomplished by means of national standards and by European Union standards. The current Turkish Aquatic Products Regulation [TAPR, 1995] states the most common and widely used 51 pesticides in Turkey with their acceptable concentrations in aquatic environment. The tolerable limits for 3 of the pesticides; endosulfan, dichlorvos and diazinon have been stated in legislation as 0.2 μg/L, 0.07 μg/L and 0.9 μg/L, respectively. The European Commission and other interested stakeholders such as ECPA, COPA/COPEGA and other NGO's reviewed how a more effective European strategy can be established for "keeping raw water resources safe from pesticides". The EU pesticide standard for drinking water is 0.1 μg/L for any individual pesticide and 0.5 μg/L in total. These standards were originally set in Drinking Water Directive 80/778/EEC and have recently been reaffirmed in the updated version of the Directive 98/83/EC. It is of particular significance to note that these standards are not based on toxicological criteria but is in effect a surrogate for zero [EUREAU, 2001]. In Europe drinking water is derived from a variety of sources including rivers, upland reservoirs and groundwater. Even though Dalyan Lagoon represents a variable brackish water character depending on seasonal seawater intrusion to the lagoon system, the analyses with current EU standard will be realized. There is actually a dual layer flow along the lagoon channel system, the upper layer flows towards the sea with a fresh-brackish water characteristic, whereas the lower layer with a high salinity flows towards the lake [*Gurel*, 2000; *Erturk*, 2002]. That is the reason why a pair water samples was collected at each sampling station for two different depths [*Gurel*, 2000].

2. DESCRIPTION OF THE LAGOON SYSTEM, WATERSHED AND SAMPLING FREQUENCY

Based on comprehensive surveys at the watershed, land-based pollutants were found to arise especially from diffuse pollutants. Forests and agricultural area cover 63% and 23% of the watershed respectively. [*Seker et al.*, 2002a]. As there exist no industries in the watershed, and as only 6 small villages are present, the land has not so far been highly deteriorated. However, fertilizers and pesticides are being applied on agricultural land where intensive agricultural activities prevail. The most important crops cultivated at the area are typical of Mediterranean climate like cotton, citrus fruits, corn, wheat, etc. Due to the climatic conditions cotton, citrus fruits and corn highly irrigated during summer months. Irrigation return water flow during summer and net precipitation in the form of surface runoff and/or leaching during the rest of the year are the only means of water and pollutant transport to the receiving water body. Rivers and creeks ending in the Koycegiz Lake just above the lagoon and in the lagoon carry part of the pollutants directly. Hydrologically during summer weak flow conditions thus weak mixing and circulation prevails leading to strong stratification along the lagoon channel [*Seker et al.*, 2002b]. During spring, freshwater inflow to the system relatively high thus such conditions urged the authors to visualize and analyze seasonal pesticide residual data.

The lagoon system consists of the main channel and two lakes, where Alagol Lake is represented by stations 3 and 4 an Sulungur Lake by stations 8, 9, 10, 11, 12 as shown in Figure 1. The rest of the sampling stations are scattered along the main channel, with station 0 and 14 representing the two boundary conditions.

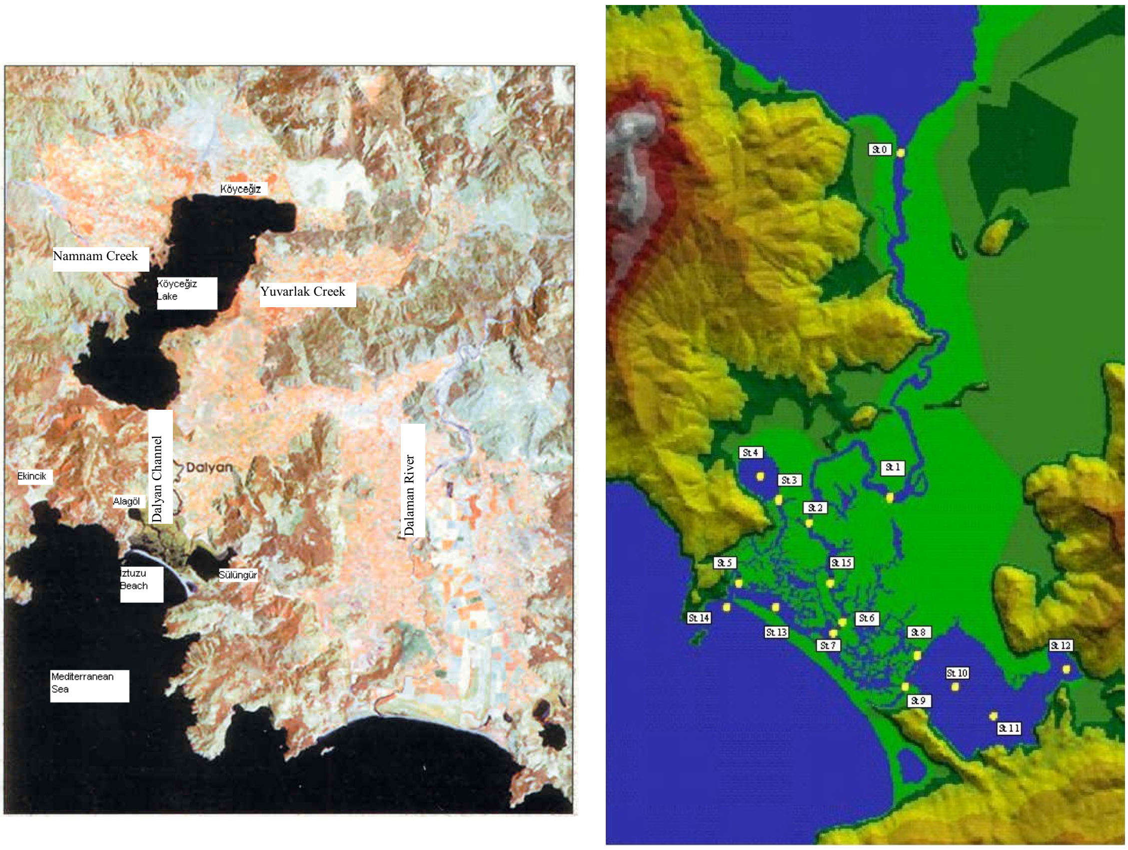


Figure 1: The lagoon system and the sampling stations

The 16 sampling stations are selected taking into account various factors as depicted by Gurel 2000.

Four cruises were realized to the area during 1999-2000 to observe seasonal variations in the system. Sampling from two layers (surface and bottom layers) was conducted at each station to monitor horizontal and vertical salinity gradients. Surface water samples were collected from 0.5 depth. Bottom layer sampling depths were chosen according to the depth of the stations and vertical salinity gradients. But these depths are above the bottom level of the channel. The cruises took place in April 1999 (spring – Cruise 1), August 1999 (summer – Cruise 2), November 1999 (autumn – Cruise 3) and March 2000 (late winter – Cruise 4). The sampling and monitoring parameters selected are of course not only limited to residual pesticides, many important parameters have been taken into account that would clarify nutrient dynamics and physical variations, etc.

This paper is focused on the seasonal distribution trend of residual pesticides that reach and appear in the water.

3. VISUALIZATION AND ANALYSES OF RESIDUAL PESTICIDE DATA BY MEANS OF GIS

In order to better visualize the seasonal variation of residual pesticides in water, both spatially and temporally, ArcView desktop GIS software has been chosen to map out the data. ArcView 3.2 is used to map out the residual pesticide at each of the 16 stations. Sampling stations have been transformed to a shape file as a first step. The next step was to take all data tables from MS EXCEL ™ and import them separately for the surface and bottom layer data into ArcView. The final step was to interpolate the grid for the cruises. Interpolate grid is a global function, which creates a grid that stores values interpolated from a point feature data set. Therefore it will be easy to determine the fluctuations during different times of the study.

In this paper, only the visualized forms of two pesticides, endosulfan and dichlorvos for surface layer of Cruise 1 and 4 are shown in Figures 2 and 3. As seen from the legend of the visualized maps, 9 different concentration ranges are chosen to demonstrate the current situation of the system.

Analyses are also conducted by using ArcView 3.2 using query commands. National tolerance limits and EU limits are considered for each of the cruises separately for upper and lower layer flows. Examples of analyses are given in Figures 4, 5, 6 and 7. Each of these figures is devoted for a different pesticide and cruise. The lighter dots indicate the responds to the queries that exceed the related limits.

Figure 4 refers to endosulfan; (a), (b) consider analyses based on National Tolerance Limit of 0.2 μg/L for two different depths (surface and bottom) of sampling whereas (c) and (d) consider the EU limits of 0.1 μg/L again in two different depths. It is seen that for this specific pesticide and cruise, tolerance limits are almost preserved. However, the more strict EU limit has been exceeded especially in the surface layer distribution. Endosulfan is listed in the Priority Pollutants with EU No: 204-079-4 in the EU List dated 20 November 2001. This fact indicates that particular attention must be paid to the application trend of this pesticide especially when applied in a sensitive coastal area. Figure 5 presents the analyses of diazinon in the same manner as of endosulfan for Cruise 2. It is seen that the national tolerance limit of 0.9 μg/L has not been exceeded in any of the surface and bottom layer samples. However the EU limit of 0.1 μg/L set for any of the pesticides has not been observed to exceed in most of the surface and bottom samplings. Figure 6 refers to dichlorvos, which is a common and highly consumed pesticide in the country with strict national limit of 0.07 μg/L. It is a highly toxic pesticide and it undergoes many reactions on both soil and water. Therefore, as inspected from the figure, the EU limit of 0.1 μg/L and the national limit of 0.07 μg/L are both so near each other as reflected in the analyses. Both the surface and bottom layer data highly exceed the accepted limits.

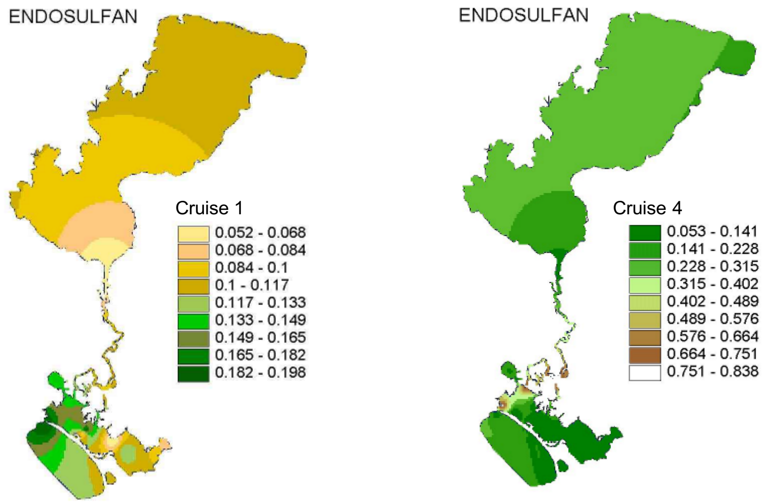


Figure 2: Visualization of residual pesticide distribution of surface water for endosulfan in Cruises 1 and 4

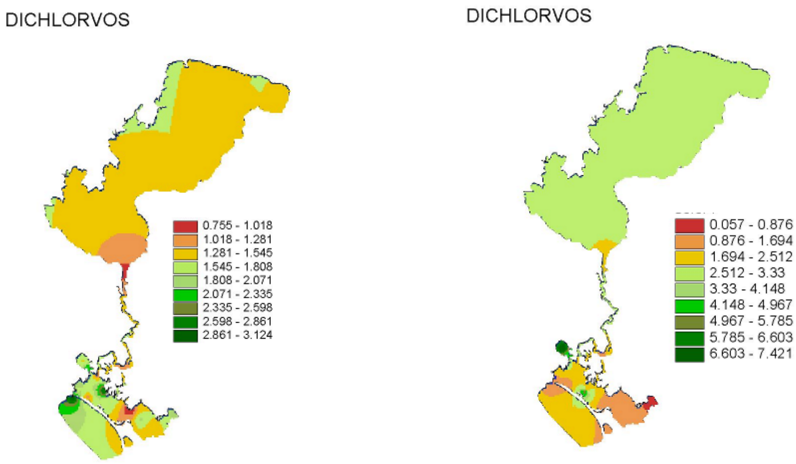


Figure 3: Visualization of residual pesticide distribution of surface water for dichlorvos in Cruises 1 and 4

This situation is a warning to the local authorities in the sense that a relatively toxic pesticide threads the water quality, and it is the only pesticide among the others applied in the area of concern that over-exceeds the limits. Figure 7 shows the example deltamethrin for Cruise 3. The national limit for this pesticide is not set therefore it is only analyzed for EU limit of 0.1 μg/L. It is observed that the limit has been exceeded in many stations, belonging both to surface and bottom layer samplings.

Such water residual analyses of some of the important pesticides are conducted, visualized and further analyzed to strengthen the expected impacts on water quality.

4 CONCLUSIONS AND RECCOMENDATIONS

In this study, visualization and analyses of seasonal residual pesticides data in aquatic environment have been accomplished using GIS as a tool. Such visualized and query maps have recently gained major interests among environmentalists, decision makers, managers and ecological modelers.

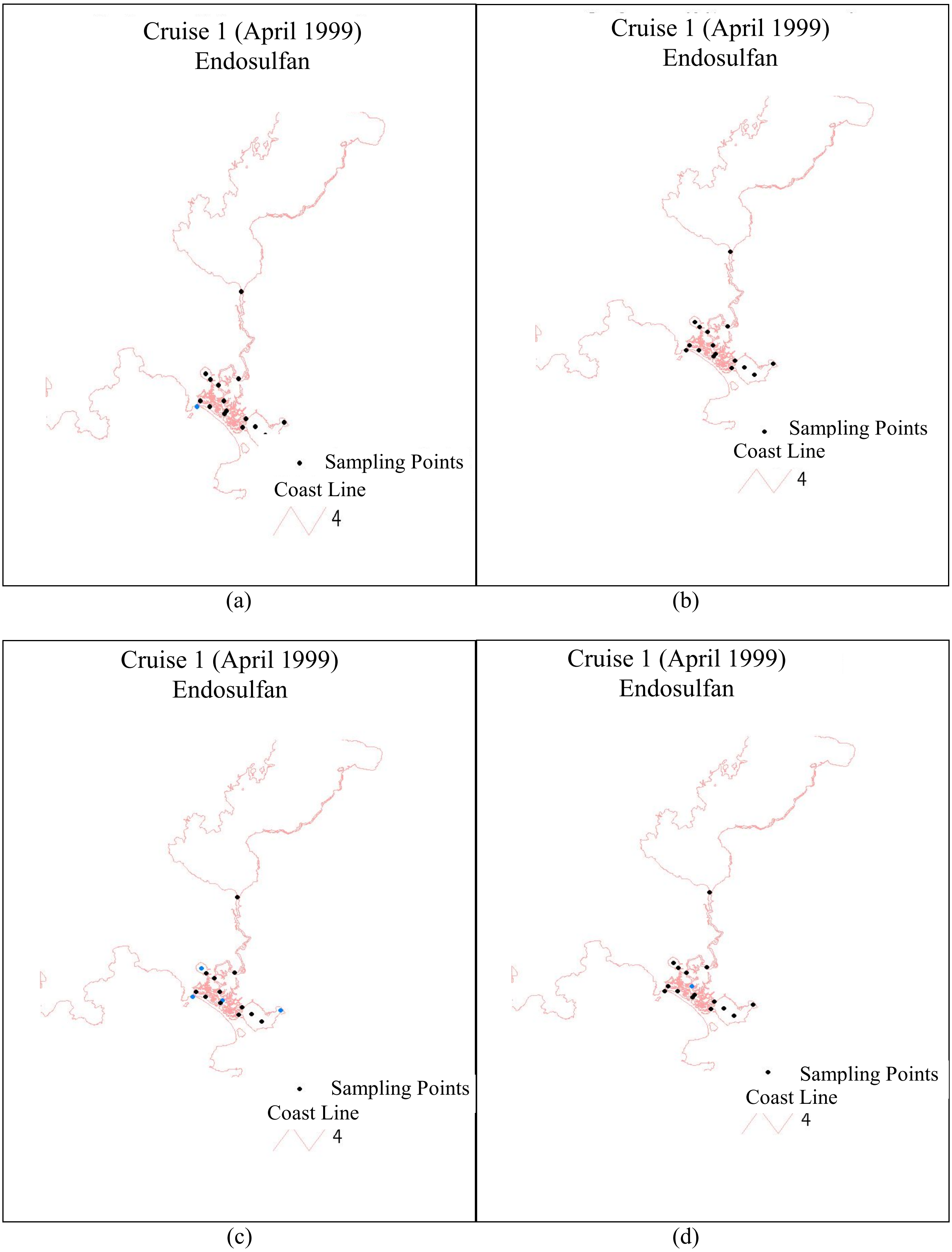


Figure 4: Analyses of residual endosulfan in water, (a) surface sampling analyzed according to national tolerance limit, (b) Bottom sampling analyzed according to national tolerance limit, (c) surface sampling analyzed according to EU tolerance limit, (d) Bottom sampling analyzed according to EU tolerance limit

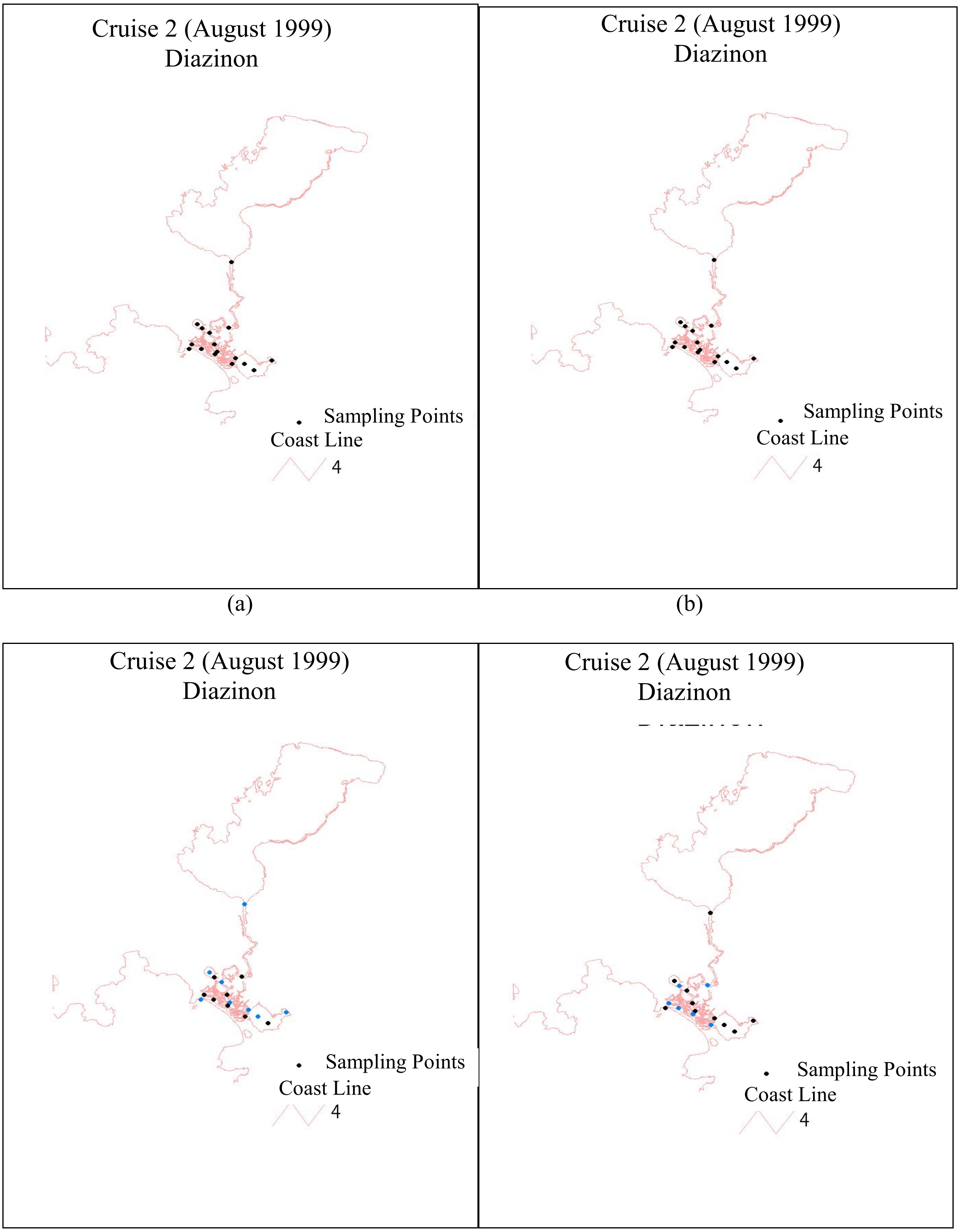


Figure 5: Analyses of residual diazinon in water, (a) surface sampling analyzed according to national tolerance limit, (b) Bottom sampling analyzed according to national tolerance limit, (c) surface sampling analyzed according to EU tolerance limit, (d) Bottom sampling analyzed according to EU tolerance limit

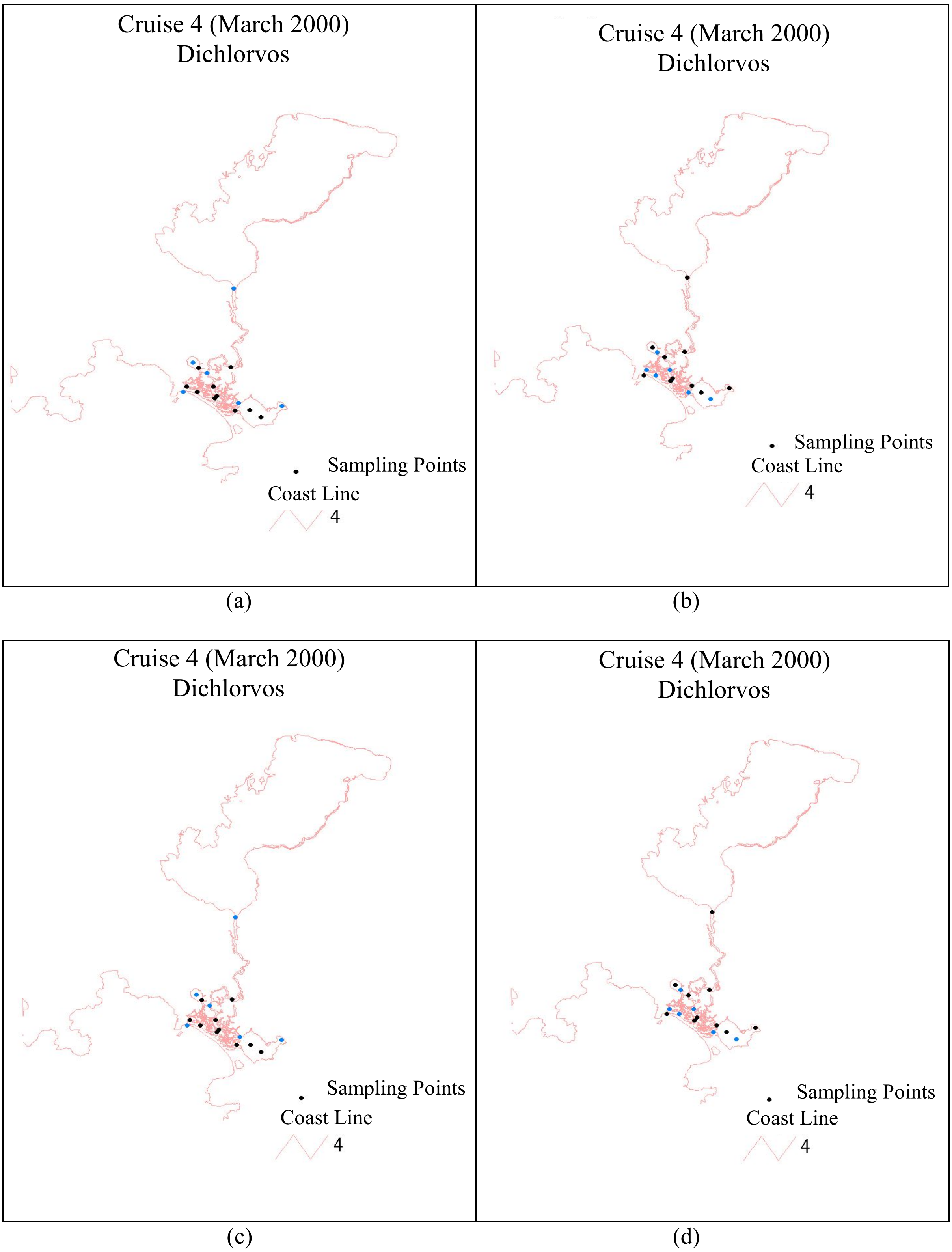
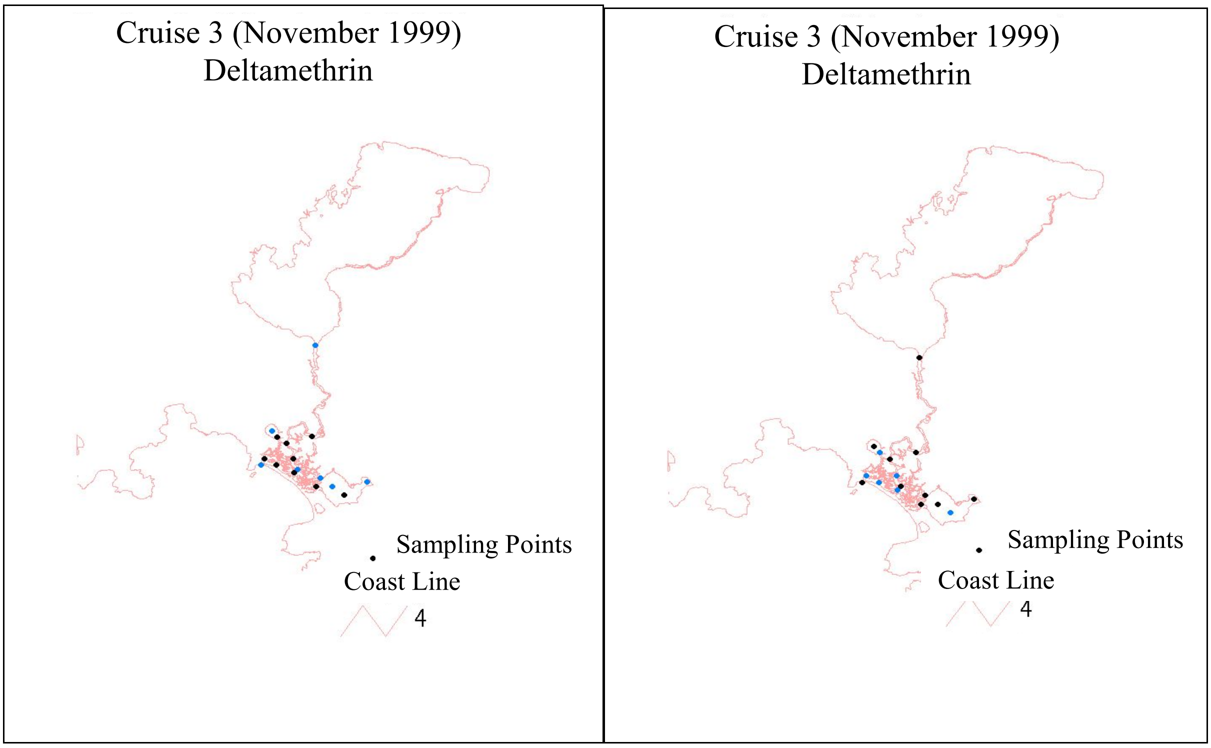


Figure 6: Analyses of residual dichlorvos in water, (a) surface sampling analyzed according to national tolerance limit, (b) Bottom sampling analyzed according to national tolerance limit, (c) surface sampling analyzed according to EU tolerance limit, (d) Bottom sampling analyzed according to EU tolerance limit



(a) (b)

Figure 7: Analyses of residual deltamethrin in water, (a) surface sampling analyzed according to EU tolerance limit, (b) Bottom sampling analyzed according to EU tolerance limit

It is a complex and difficult task to estimate the fate of a pesticide in the aquatic environment as the reactions are significantly influenced by abiotic and biotic factors. To assess its/their fate, usually models became more valuable. Various models are available that would be applied to similar cases, however in such experiences, external factors like climatic conditions and soil properties together with intrinsic properties of pesticides analyzed must be predetermined and further integrated to the model. Such an approach would better put forth the existing situation and assessments and verifications would be easily achieved. During these attempts, the use and application of GIS technology quickens the procedure and helps to interact new data to the system for forecasting future conditions. Manipulations will be easier and model integrations will be much easier.

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