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Assessment of Surface Water Quality in Côte d'lvoire

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The water systems in Côte d'Ivoire is composed of four main rivers and three lagoons. The rivers cut across the geographic regions from the north to the south to the Gulf of Guinea. Most of the lagoons are narrow, salty and shallow and are parallel to the costline. These lagoons become broad estuaries where the larger rivers empty. Rivers and lagoons serve as important waterway for the transportation of goods and people. They are also important source of animal proteins in form of fish. Above all, the water systems represents a source of domestic water supply for rural as well as urban communities.

With the development of commercial agriculture, the improvement of food production, and the need to protect human health against insects vector of disease the use of chemical fertilisers and pesticides has markedly increased in the country. These chemicals released in the environment may reach surface and groundwater where they may persist for long periods.

A number of studies have been done on the pollution of water systems in Africa. Ayayi So and Osibanjo O. (1981) reported on water quality of some Nigerian rivers. El-Dib and Badawi (1985) reported the presence of organochlorine pesticides and PCBs in the River Nile. In 1978, Greichus, Y.A. and al. investigated Lake Nakuru in Kenya for the presence of insecticides, PCBs and metals. But until now no study has been conducted to determine the amount and the fate of pollutants in the water systems in Côte d'Ivoire. This work aims at establishing a base-line levels of various pollutants.

MATERIALS AND METHODS

Nine collection sites (Six on rivers and three on lagoons) located in areas of intense agricultural practice were selected for the study (Fig 1). Water samples for analysis were collected from October to November. The samples were collected mid-stream at depths of 15-20 cm by dipping the glass containers into the river or lagoon from a row boat. Five samples of 5 L were collected from each sampling site for the measurement of the physicochemical characteristics (temperature, pH, color, total hardness, alkalinity, suspended solid, Do, and COD), heavy metals (Cr, Se, As, Zn, Cd, CU, Hg, and Pb), and organochlorine pesticides.

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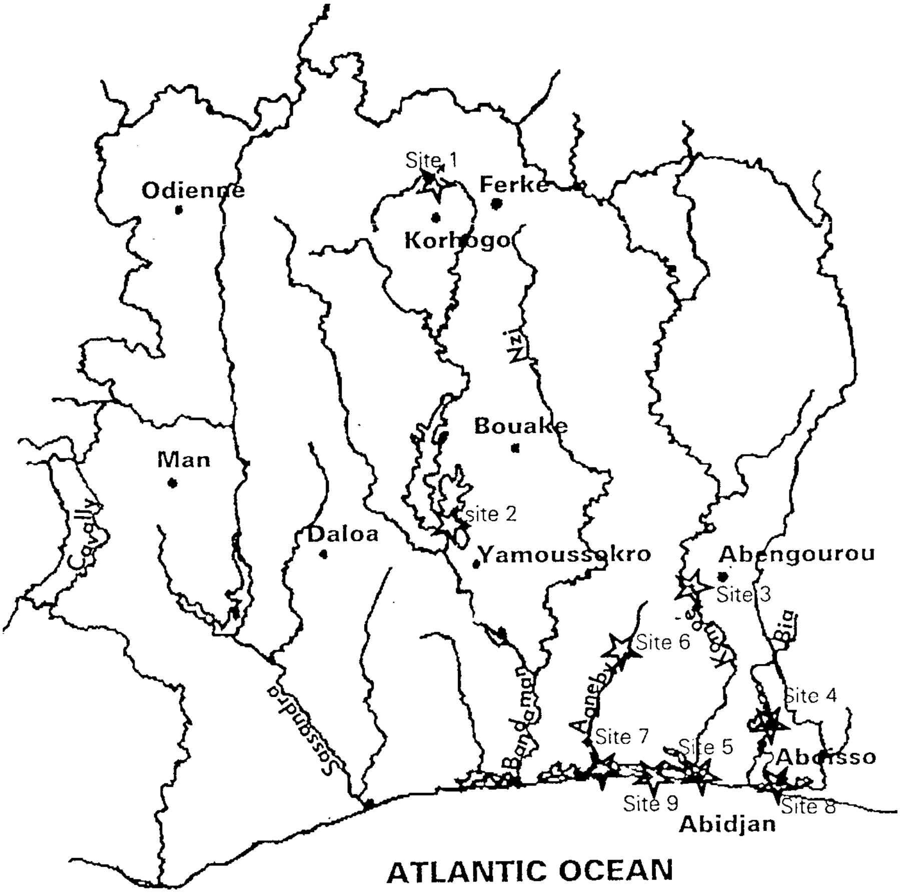

Figure 1. Map of Cote d’Ivoire showing sample collection sites.

The physicochemical properties of the samples were determined according to the standard methods for the examination of water and wastewater (Clesceri et al., 1989). DO were determined by the azide modification of the Winkler’s method on dilute sample (Hanan 1973). Suspended solid were determined by filtering a known volume of water through a glass fibre membrane (0.25 µm), drying and weighing. pH was determined with a direct reading pH meter (Beckman PHΨ 72), standardized with acetate and phosphate buffers at pH 4.0 and 9.2 respectively. Alkalinity was determined by titration of 50 ml sample with 0.01 M H_2SO_4 using phenolphthalein and a mixed indicator bromocresol green-methyl red. Total hardness was determined by means of EDTA titration using Eriochrome black T indicator.

One Hundred ml of water sample were filter through glass fiber (Whatman Gf 0.5 µm). The filtrate was acid digested and passed through a column (Econo pack, Millipore) filled with chelex-100 resin (hydrogen form, 200-400 mesh, 3 nm pore diameter) obtained from BioRad Laboratories, CA. The resin columns were kept frozen until their transportation to the USA. In the USA, the heavy metals retained in the columns were eluted with strong NO, acid and analyzed by ICP (Termo Jarrell Ash, Polyscan 61E). The limits of detection were 10, 100, 50, 5, 5, 5, 50, and 20 µg/L for Cr, Se, As, Zn, Cd, Cu, Hg, and Hg respectively.

The solid phase extraction (SPE) procedure was adapted from the method provided by Alltech Associates, Inc (Anonymous). The solvents used were "pesticide residue grade". Sep-pack cartridges (Alltech Associates, INC) containing 1000 mg of packing material (C&-bounded silica) were used for sample collection. The cartridges were coupled to a filter flask. The cartridges were washed with 10 ml hexane followed by 10 ml ethyl acetate. The cartridges were dried briefly, under vacuum to remove excess solvent and were conditioned with 10 ml methanol (MeOH) then 10 ml deionized water.

Five hundred ml separatory funnel containing 250 ml of water samples was connected to the cartridge and water was passed through the column, by hand suction at a rate of approximately 15 ml/mm The cartridge were then stored at 4°C until transportation to the USA.

In the USA, the cartridges were inserted into a vacuum manifold and dried at a pressure of 500 mbar. The columns were then washed with 10 ml deionized water followed by 10 ml MeOH:deionized water (20: 80 v/v). The absorbed pesticides were eluted with a solution of hexane:ethyl acetate (70:30) at a flow rate of approximately 2-3 ml/min until 4 ml were collected.

A Hewlett Packard 5890 Series II gas chromatograph equipped with a Ni^{63} electron capture detector (ECD) and a DB-5 fused capillary column (30 m x 0.333 µm id) was used for the final organochlorine pesticides (OCP) analysis. Injector, column, and detector were operated at 270, 275, and 200° C respectively. Helium was used as carrier gas and nitrogen as make-up gas. The limits of detection for the pesticides were 0.04, 0.2, 0.04, 0.02, 0.15, 0.5, 0.03, 0.09 µg/ml for aldrin, p,p'-DDE, p,p'-DDT, dieldrin, endosulfan, endrin, heptachlor, and lindane respectively .

RESULTS AND DISCUSSION

Physicochemical properties for the selected rivers and lagoons are given in table 1. The temperature of water of the lagoons are higher than the temperature of water from the river. The lagoons are large water bodies with more evapotranspiration compared to rivers. The mean pH of 7.18 was within the range of the WHO recommendation of 7.0 - 8.5 for drinking water. The high value observed at site 9 may be attributed to the industrial activities surrounding the area. Total hardness ranged between 21.2 and 41.5. Most of the values are below 40 mg/L therefore these waters are not as soft. As the color index indicated, most of the water samples are clear. The turbidity observed at sites 1 and 2 were attributed to the recent rainfall. The turbidity as well as the brown color observed at sites 5 and 9 may be attributed agricultural and industrial activities surrounding these sites. The COD observed increased from the north to the south of the country, principally in the capital city. The increase in COD was attributed to the increase of organic matter due to agriculture (pesticides, fertilisers), urbanisation (waste water) and industrialization (oil refineries, food processing plants, etc..).

Table 1. Physico-chemical properties of water samples collected

Mean values	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Temperature oC	27.4	28.0	27.7	27.2	26.7	27.2	31.3	30.5	31.7
PH	7.6	7.2	7.1	6.8	6.5	6.2	6.9	7.5	8.9
Color	85.5	15.3	87.2	25.2	88.5	75.7	15.4	13.2	89.3
Total Hardness mg/L	39.2	29.4	28.4	31.0	37.0	35.2	41.5	42.0	21.2
Total solid mg/L	45.2	15.2	50.0	22.5	32.1	44.4	20.3	15.2	19.6
DO	5.4	2.3	8.2	3.5	10.1	10.2	11.2	10.1	12.2
Total alkalinity	15.0	5.5	17.2	4.2	17.0	16.5	20.1	21.2	30.2
COD	87.0	102.0	145.0	105.0	125.0	130.0	121.0	103.0	245.0

The average concentrations of metals in water samples are given in table 2. Cr, Se, As, Cd, Hg, and Pb were not detected. Zinc and copper were detected but in general at low levels.

Table 2. Inorganic contaminant levels (µg/L) in water samples. Mean from five determinations

	Sampling Sites								
Contaminants	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Cr	<10	<10	<10	<10	<10	<10	<10	<10	<10
Se	<100	<100	<100	<100	<100	<100	<100	<100	<100
As	<50	<50	<50	<50	<50	<50	<50	<50	<50
Zn	45	58	70	42	1730	731	310	<5	32
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cu	<5	7	7	<4	<5	10	<5	7	<5
Hg	<50	<50	<50	<50	<50	<50	<50	<50	<50
Pb	<20	<20	<20	<20	<20	<20	<20	<20	<20

For statistically evaluating the extraction efficiency of the target& pesticides by SPE techniques, 500 ml of distillated water from our laboratory was fortified with the compounds al three concentration levels (0.035, 0.055, 0.25 pm).

The results of the recovery study are presented in Table 3. The average recoveries were between 72 and 105 % except for aldrin and endosulfan with 41 and 50 %. The relative standard deviation was between 2 and 22% (in accord with residue analysis, Greve 1984).

Table 3. Mean recovery (%) ± RSD (n= 3) for the pesticides

	Spiking Levels (µg/L)		
Pesticide	35.0	55.0	250.0
Aldrin	41 ± 4	45 ± 5	50 ± 5
DDD	98 ± 11	88 ± 4	102 ± 5
DDE	101 ± 5	99 ± 2	77 ± 3
DDT	97 ± 7	102 ± 5	78 ± 5
Dieldrin	105 ± 5	77 ± 9	72 ± 7
Endosulfan	55 ± 6	46 ± 12	49 ± 5
Endrin	96 ± 4	97 ± 5	92 ± 11
Heptachlor	92 ± 6	95 ± 4	105 ± 7
Lindane	92 ± 6	102 ± 11	99 ± 6

Identification and quantitation of compounds was accomplished using reference solutions of a mixture containing the targeted pesticides. 0.01 to 0.08 pm of the mixture solution were injected into the GC and a standard curve was determined and used to quantified the solutes in the samples.

Results given in table 4 present the concentration levels of organochlorine pesticides in water samples from the nine collection sites. Among the targeted pesticides, five were found in the water samples. Dieldrin and lindane occurred in all the samples except in the samples from site 1. p,p'-DDT and endosulfan were detected in samples from 6 sites whereas aldrin was found only at three locations. The mean concentration of aldrin , p,p'-DDT and dieldrin were 0.3 µg/l, 0.5, and 0.4 µg/l respectively. The concentration of endosulfan was 1,7 (range 1.3-1.9). The mean concentration of lindane was 2.6 (range 0-3-3.9)

The concentration of organochlorines insecticides in water samples are considerably lower than that reported in River Nile by El-Dib and Badawy (1985) and in several African lakes (Greichus, 1978). The residue levels of the studied compounds are still low compared with the permissible levels for drinking waters (Train, 1979, WHO, 1982).

Table 4. Organochlorine pesticides levels (µg/L) in water samples from the nine collection sites. Mean from five determinations. nd = non detected. Detection limit between 0.05-0.5.

	Collection Sites								
Compound	S.1	S.2	S.3	S.4	S.5	S.6	S.7	S.8	S.9
Aldrin	nd	nd	nd	nd	nd	nd	0.3	0.3	0.5
p,p'-DDE	nd	nd	nd	nd	nd	nd	nd	nd	nd
p,p'-DDT	nd	nd	nd	0.4	0.5	0.3	0.5	0.5	0.6
Dieldrin	0.1	0.2	0.3	0.5	0.4	0.4	0.5	0.4	0.6
Endosulfan	nd	nd	nd	1.3	1.7	1.7	1.9	1.9	1.9
Endrin	nd	nd	nd	nd	nd	nd	nd	nd	nd
Heptachlor	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lindane	nd	0.3	1.1	3.1	2.9	3.1	3.2	3.3	3.9

The results of the study show that the levels of OC found in water samples is higher in the south than in the north of the country. For example the mean concentration of lindane in the river Komoe was 1.1µg/L at site 3 (upper Komoe) and 2.9 µg/L at site 5 (lower Komoe). Since the rivers flow from the north to the south it is expected to find more pesticide in the south. The results show levels of OC in the lagoons is higher than in the rivers. This was explained by the fact that most of the river flow into the lagoons. The findings can also be explained by the difference in agricultural activities; in the north of the country only cotton, and recently sugar cane are grown whereas most of the commercial crops are grown in the south.

The residue levels of lindane (range 0.3-3.9) and endosulfan (range 1.3-1.9) were higher than those of the other compounds. This finding can be explained by the fact that lindane and endosulfan are still used in the country. Endosulfan is used in crop protection as insecticide against termites and variegated grasshopper and as nematocide in banana production. Endosulfan is also use against vectors of diseases. Lindane is extensively used against cocoa mirids and other pests (Anonymous). Aldrin found at three sites in the south (lagoons) might infer recent usage. Although aldrin is officially banned in the country, it can still be purchased by farmers in the black market.

The present study shows that the rivers and lagoons investigated do not appear at present to be a pollution problem. The physicochemical characteristics are in the normal range. The organochlorine pesticides when found are at a very low level. This is true for metals although it is difficult to distinguish between naturally occurring metals and those due to human activities. Because the increase in the agricultural activities and industrialization will result in greater output of xenebiotics in the environment, there is a need to continuously monitor the quality of the water systems. There is also a need for further study which will take in account seasonal variation, different water depths, and sediment.

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