HEAVY METAL POLLUTION IN THE INTERSTITIAL SEDIMENTS OF ACCRA - TEMA BEACHES

BY

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INTRODUCTION

The early man lived in a world that, with respect to the amount of energy per capita, suffered little from the one which existed since he became a recognisable species. However, modern man's quest of bringing enlightenment and comfort to the ever increasing population through exploits of science and technology has brought in its wake pollution of the environment, a problem of great concern in our world today.

The problem of pollution became widely recognised during the 1960's. Although many billions of dollars have been invested all over the world in the solution of the problem, we are still far from an acceptable solution to the serious problems emanating from pollution that threaten the survival of Homo Sapiens. Some concerned groups even claim that we are further from a total solution of our environmental problems than we were 10 to 20 years ago owing to the continuous growth of population and continuous depletion of natural resources. [1]

Pollution can result from natural sources and can also be man-made. Natural substances that cause pollution include radioactive fall out which pollutes the air and other media such as surface and groundwaters as well as vegetation. Others are decay bodies of animals and plants, dust, volcanic activities and continental weathering. [2]

Man-made or anthropogenic activities that pollute the environment include direct discharge of untreated sewage, garbage, domestic and industrial waste waters directly or through run-offs into water bodies. Other contributors are aerosol sprays, mining and smelting activities.

Agricultural waste which are discharged directly and through run-offs into water bodies do also cause pollution. Clearing of the forest and burning of the forest by man also leave soil surfaces bare and vulnerable to erosion into water bodies. There is also oil spillage from cars, tankers and refineries which directly and indirectly introduce oil into water bodies. [3]

Generally, these pollutants go to deplete the oxygen content of the water bodies, increase or decrease their pH and conductivity and increase particulate matter and concentration of heavy metals.

Even though the various pollutants mentioned above may affect all the water bodies, it is believed that the final destination of all the pollutants is the sea, thus the marine ecosystem act as the reservoir for diverse kinds of pollutants. The sea is one of the major natural sinks through which nature demonstrates its capacity to disperse, degrade, absorb or otherwise dispose of unwanted residues. Other natural sinks are the atmosphere and the soil.

Separating the sea from the main land and between the limit of the motorable road and the sea where a lot of human activities occur is the beach. It serves as working places, markets, oil drilling site, recreational or holiday resorts and sporting activity centres. For these purposes, human settlements are found very close to the beaches, in taking them places where domestic wastes are sometimes dumped.

Stretching between the shore and the edge of the continental shelf that contains shallow water, where the sea bed makes a sudden drop to the ocean depth is the **interstitial zone.** [4,5]

It is the space of land between the limits of the sea at high and low tides. Sediments found in this zone are of great importance as far as pollution of beaches is concerned. At high tide, the sea moves landwards carrying a lot of particulates, debris, metals, etc. which are all deposited at the zone during low tide when the sea retreats. Some of these pollutants are left at the surface of the sediments but others especially, heavy metal salts that are soluble percolate through the sediment at different degrees and are adsorbed onto the surface of the sediments. These pollutants could come from the various sources already mentioned. However, the partitioning or distribution of heavy metals in sediments depends on many variables or parameters such as pH, valency of the metal, degree of hydration, nature and surface area of the sediments and density of the metal involved. [6]

A vast array of pollutants can interact with the body in all kinds of ways when ingested, but the heavy metals are considered to be of prime concern as far as health and biological needs of the body are concerned. The metals Fe, Pb, Sn, Mn, Cr, Ni, Co, Zn, Ag, Hg and Cd are normally present in relatively low concentrations in the environment. At reasonably low concentrations, some of these metals are essential to living organisms for metabolism but in high concentrations they become toxic and dangerous. Essentially, they are constituents of enzymes, vitamins, pigments and other important proteins involved in key metabolic pathways. [7] At concentrations exceeding the tolerable levels of the body, these metals cause diseases such as cancer, blindness, mental retardation, high blood pressure and even death in extreme cases. The metals can react with proteins, DNA, RNA and other substances affecting metabolic processes.

They can cause enzyme inhibition and thus change the rate at which catalysed decomposition of metabolites take place. [8,9] Some of the well-known toxic metals are Cd, Pb and Hg, which can cause severe neurological impairment.

Heavy metals have now become the commonest pollutant in our environment today due to diverse activities of man. In fact, recent research findings reveal a drift of many heavy metals from terrestrial and atmospheric environment, into the bottom sediments where they are adsorbed into clay and humic particles[10], lagoon sediments[12,13], sea water and marine organisms[11] but very little work has been done on marine sediments from the interstitial zone especially in Ghana.[11]

A potential health threat coupled with lack of adequate in information on heavy metals and their levels along the beaches of Ghana arouses an interest into this work. The main objective of this work is therefore to determine the levels of some selected heavy metals in the sediments to ascertain the degree of trace metal pollution of the Ghanaian beaches and to determine to relationship between the levels of the heavy metal and particle size of the sediments as well as the depth. Ghana, like the other developing countries in the West African sub-region, has seen active industrialisation in the recent times. One other thing common to these countries is the establishment of the major industries in the coastal cities with its attended problems of human migration from the inland to the coastal cities.

The coastal zones of Accra and Tema with a high concentration of urban and industrial establishments are also the most densely populated part of the country. It is also interesting to note that about 60% of Ghana's industrial establishments are located in the Accra-Tema metropolis alone[12], which covers less than 1% of the total area of the country. The ever-increasing population coupled with the rapid proliferation of industries and settlements in these metropolitan areas pose a future threat to the fragile ecosystem and this should attract attention of researchers.

The accelerated urbanisation and industrialisation in the Accra-Tema metropolitan area in recent years has brought in its wake problems with heavy metals and other forms of pollution. This situation has been aggravated by the concentration of the industries in the metropolis, thereby localising the effect of heavy metal and other forms of pollution. This therefore, necessitated the choice of the area in this work which is apart of a bigger project to map out pollution indicators in the interstitial zone of West Africa, the Gulf of Guinea.

The choice of sampling point was arbitrary, however the beaches of Owene, Riviera, Sakumono and Kpone were chosen since they are among the popular beaches found within the Accra-Tema metropolis and also because of differences in influence from human settlements in industries.

Owene is a low-class, high-density area, with density of more than 350 persons per hectare. It is an economically depressed, old and indigenous town with settlements very close to the beach.

The planning of the town is quite poor and the situation is even serious considering the proximity of the numerous wooden structures, serving as dwelling places, to the coast. The main occupation of the inhabitants is fishing.

Riviera is however a non-residential area. It has a high concentration of governmental establishments and firms, business and financial institutions, state ceremonial grounds (the Independent Square) and the Christianborg castle which is the seat of government. It is a well-planned area, very close to the heart of the capital. Dwelling buildings are quite far from the coast.

Sakumono is a high class, low-density residential area with approximate density of 50 persons per hectare. It is a well-planned township and the dwelling houses are far from the beach even further than that of the Independent Square.

Kpone is a fishing village that is situated at a distance of about 5 km east of Tema, the location of many of the country's large industries including the country's biggest fishing and shipping harbours. Considering the proximity of human settlements to the coast, Kpone, compared to the other sampling areas is the farthest but the sea here has the disadvantage of accepting large industrial effluents from Tema and also harbours some scrap ships.

EXPERIMENTAL

SAMPLING AND SAMPLE TREATMENT

Sediment samples were taken from the intertidal zone at the four beaches namely Owene, Riviera, Sakumono and Kpone all along the coast of Accra and Tema as shown in Fig. 1. In each case, sample were taken from six different depths, 5.0, 10.0, 15.0, 20.0, 25.0 and 30.0 cm using an Auger sampler. Samples were poured into polythene bags and stored in a refrigerator. To prevent atmospheric contamination, Samples were dried in a confined place under an air condition room temperature of 22°C for 72 hours. The dried samples were then collected and kept in a clean dry transparent polythene bag ready for aggregate size analysis

AGGREGATION ANALYSIS

After homogenisation, 100g of each sediment was passed through a sieve arrangement with pore/mesh sizes ranging from 1.70 to 0.15 mm and shaken on an electronic shaker for 7 minutes. This separated the sediments into their various particle sizes. The weight of each aggregate range was measured by taking the weight of the sieves before and after the analysis by means of a top loading balance. The various particle sizes were kept in separate polythene bags for the next analysis.

HEAVY METAL ANALYSIS

Particle sizes of below 0.315 mm were finely ground by means of a mortar and pestles and used for the digestion in each case. A closed digestion system using Teflon bomb was employed.

In this digestion system, about 0.02g of each sediment was digested with 2.5-ml of concentrated HNO_3 using a Teflon bomb at a temperature of 120°C for 1 hour and then at 160°C for 8 hours. The bomb was allowed to cool to room temperature after which the liquid acid portion of the content of the beakers containing the dissolved metal ions was decanted into a graduated test tube. The acid solution was made to 10ml with de-ionised water and kept in a plastic container which has been pre-treated by soaking in 1.5m HNO_3 overnight.

A blank was prepared in each case by using 2.5-ml concentrated HNO_3 and following the same procedure above but without the sediments. An open digestion method was also tried but the results were found to be unsatisfactory compared to the results from the closed digestion using the Teflon bomb. In the open digestion method, between 0.25 - 0.30g of each sediment was weighed into a 100ml Pyrex beaker previously washed with a detergent and soaked in a 1.5M HNO_3 and dried in an oven. 4-ml of concentrated HNO_3 was added and the beaker and its content evaporated on a hot plate to near dryness to remove most organic matter in the sample.

This was followed by addition of 5ml of a mixture of concentrated HNO_3 and $HClO_4$ in 3:2 ratio and also evaporated to near dryness. The beaker and its content were cooled to room temperature after which it was rinsed with de-ionised water and filtered using a filter paper of 0.45µm pore size into a 50ml volumetric flask and the solution made up to the mark. The solutions were kept in a well stoppered plastic containers pre-treated by soaking overnight in 1.4M HNO_3 and rinsed with de-ionised water. Blank solutions were also prepared following the same procedure but omitting sediments.

The metal content of the samples were measured using a Pye Unicam Model PU-9200 Flame Atomic Absorption Spectrophotometer (FAAS) by Pye Unicam.

For each metal, a specific hollow cathode lamp was used and the instrument was calibrated by using serially diluted standard solutions of the metal of interest.

Parameters of the Spectrophotometer for the metals determined are shown in Table 1 below:

TABLE 1: _PARAMETERS OF THE SPECTROPHOTOMETER USED FOR THE METALS DETERMINED_

Metal	Wavelength (λ) nm	Flame Type	Detection Limit (ppm)	Sensitivity (ppm)
Mn	279.5	OA	0.001	0.052
Zn	218.9	OA	0.010	0.010
Ni	232.0	OA	0.030	0.100

OA = Oxygen-Acetylene

RESULTS AND DISCUSSION

The results obtained from the aggregation analysis are shown in Table 2 to Table 5 in Figure 2 to Figure 5. aggregation size distribution of sediments from the same beach taken from different depths follows the same particles size distribution pattern, but this pattern differs from the other beaches.

Table 2 show the weights in gram of various aggregate sizes at each depth for sediments collected at Owene Interstitial zone, whilst Tables 3,4 and 5 show those for Riviera, Sakumono and Kpone respectively.

Table 2:   _Aggregate Size distribution of sediment sampled at Owene interstitial zone_.

AGGREGATE SIZE (PORE SIZE) / mm	DEPTH AND CORRESPONDING WEIGHT OF AGGREGATES/g					
	5.0 cm	10.0 cm	15.0 cm	20. 0 cm	25.0 cm	30. 0 cm
>1.70	0.10	0.19	0.61	0.31	0.25	0.47
1.70 - 1.25	0.35	0.31	0.72	0.66	0.83	0.79
1.25 - 0.63	6.60	8.14	9.32	12.64	12.19	10..82
0.63 - 0.40	32.57	31.78	29.44	32.21	30.72	27.83
0.40 - 0.315	35.86	31.64	37.39	31.72	34.65	34.35
0.315 - 0.25	18.22	21.88	17.59	17.13	17.14	18.9
0.25 - 0.20	5.43	5.32	4.73	5.18	4.01	6.50
0.20 - 0.15	1.10	0.64	0.14	0.18	0.25	0.22
< 0.15	0.07	0.06	0.06	0.07	0.04	0.01

Table 3: *Aggregate size distribution of sediments sampled at Riviera interstitial zone*

AGGREGATE SIZE (PORE SIZE) / mm	DEPTH AND CORRESPONDING WEIGHT OF AGGREGATES/g					
	5.0 cm	10.0 cm	15.0 cm	20. 0 cm	25.0 cm	30. 0 cm
>1.70	0.01	0.00	0.00	0.00	0.05	0.09
1.70 - 1.25	0.02	0.00	0.00	0.00	0.10	0.14
1.25 - 0.63	0.16	0.06	0.28	0.18	0.90	1.76
0.63 - 0.40	2.15	0.66	1.63	1.76	2.42	4.19
0.40 - 0.315	4.01	2.63	3.42	4.53	5.72	10.00
0.315 - 0.25	28.09	12.03	13.25	21.80	15.15	61.22
0.25 - 0.20	32.83	48.63	45.27	43.71	41.92	16.07
0.20 - 0.15	29.57	29.71	31.52	27.71	32.73	6.49
< 0.15	3.20	6.29	4.55	0.42	1.01	0.05

Table 4: *Aggregate size distribution of sediments sampled at Sakumono interstitial zone*

AGGREGATE SIZE (PORE SIZE) / mm	DEPTH AND CORRESPONDING WEIGHT OF AGGREGATES/g					
	5.0 cm	10.0 cm	15.0 cm	20. 0 cm	25.0 cm	30. 0 cm
>1.70	0.64	4.40	3.85	4.11	5.60	4.29
1.70 - 1.25	1.44	5.44	6.72	5.48	5.50	4.95
1.25 - 0.63	24.50	31.32	37.34	31.52	31.07	30.49
0.63 - 0.40	19.34	16.29	14.27	14.95	15.66	18.06
0.40 - 0.315	10.76	8.82	5.50	5.44	8.58	8.83
0.315 - 0.25	9.06	7.82	7.36	9.22	7.06	7.23
0.25 - 0.20	15.74	13.68	12.47	14.62	13.90	12.70
0.20 - 0.15	15.78	9.94	9.77	11.63	10.11	10.92
< 0.15	2.85	2.20	2.64	2.86	2.29	2.49

Table 5: Aggregate size distribution of sediments sampled at Kpone interstitial zone

AGGREGATE SIZE (PORE SIZE) / mm	DEPTH AND CORRESPONDING WEIGHT OF AGGREGATES/g					
	5.0 cm	10.0 cm	15.0 cm	20. 0 cm	25.0 cm	30. 0 cm
>1.70	0.10	0.19	0.61	0.31	0.25	0.47
1.70 - 1.25	0.35	0.31	0.72	0.66	0.83	0.79
1.25 - 0.63	6.60	8.14	9.32	12.64	12.19	10.82
0.63 - 0.40	32.57	31.78	29.44	32.21	30.72	27.82
0.40 - 0.315	35.68	31.64	37.39	31.72	34.65	34.35
0.315 - 0.25	18.22	21.88	17.59	17.13	17.14	18.95
0.20 - 0.15	1.01	0.64	0.14	0.18	0.25	0.22
< 0.15	0.07	0.06	0.06	0.07	0.04	0.01

Sediments from Sakumono showed the widest distribution of particle size ranging from coarse grains through medium grains to fine grains, with a greater proportion having particle sizes between 1.25 - 0.63 mm with particle sizes of <0.15 mm being the smallest fraction as shown in Figure 4. The particles of sediments observed at Owene however are of larger sizes or coarse grains with sizes between 1.7 - 0.40 mm with a greater portion having particle size of between 1.25 - 0.63 mm. Particle sizes of between 0.40 - <0.15 mm constitute a small proportion, with 0.25 mm aggregate being the least as shown in Figure 2. Figure 5 shows that almost all the aggregates of sediments observed at Kpone were between the particle sizes of 0.63 - 0.20 mm. The greatest proportions of particles fall within particle size range of 0.315 - 0.40 mm. As shown in Figure 3, the sediments at Riviera are the finest but unlike Kpone and Owene, almost all the aggregates are within the particle sizes of 0.315 - 0.15 mm. The constituent particles with sizes less than o.25 mm but greater than 0.15 mm constitute the greatest proportions at this beach.

The variation in the particle size distribution of sediments along the different beaches could not easily be explained. It may however, be due to the natural geological pattern of sediment formation through weathering as a result of the geological rock type of the area. Whilst it is expected that the finest grains of particle size will be at Owene where we have the most human activities due to human pressure on the sediments and the corresponding coarser grains of sediments at Riviera and Sakumono where there are relatively low human activities, the opposite is rather the case. One other factor, which can affect or influence distribution pattern of sediments, is the wave pattern of the sea. Further studies may reveal this influence.

TRACE METALS

The results obtained from the trace metal analysis are shown in Tables 6 and 7 and in Figure 6 to Figure 8. Table 6 shows the comparison of concentrations of some trace metals in mg/kg adsorbed by the various particle sizes of sediments sampled from Sakumono taken at 15 cm depth.

Table 6:   *Dependence of some trace metals of concentration on aggregation size of sediments sampled from Sakumono at 15 cm depth*

PORE SIZE / mm	CONCENTRATION IN mg/kg		
	Mn	Zn	Ni
>1.70	BDL	2.93 ± 0.09	9.79 ± 2.41
1.70 - 1.25	BDL	1.98 ± 0.01	8.91 ± 0.60
1.25 - 0.63	3.48 ± 2.01	2.49 ± 0.33	9.42 ± 0.42
0.63 - 0.40	16.48 ± 1.55	5.55 ± 0.34	14.08 ± 6.84
0.40 - 0.135	12.75 ± 2.30	3.43 ± 0.12	10.78 ± 4.13
<0.30	7.49 ± 0.41	3.99 ± 0.11	15.98 ± 5.05

BDL   =   Below Detection Limit

Table 7:   *Mn and Zn Trace Metal Concentrations in mg/kg measured in the sediments sampled at the various interstitial zones*

7A: Owene

Sample Depth/cm	Mn	Zn
5.0	17.45 ± 1.17	43.26 ± 2.44
10.0	26.85 ± 0.97	9.45 ± 1.22
15.0	24.58 ± 0.07	14.75 ± 0.90
20.0	20.76 ± 0.21	16.81 ± 0.72
25.0	25.42 ± 0.25	18.44 ± 1.21
30.0	14.36 ± 2.90	16.34 ± 1.21

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1.70 - 1.25	BDL	1.98 ± 0.01	8.91 ± 0.60
1.25 - 0.63	3.48 ± 2.01	2.49 ± 0.33	9.42 ± 0.42
0.63 - 0.40	16.48 ± 1.55	5.55 ± 0.34	14.08 ± 6.84
0.40 - 0.135	12.75 ± 2.30	3.43 ± 0.12	10.78 ± 4.13
<0.30	7.49 ± 0.41	3.99 ± 0.11	15.98 ± 5.05

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5.0	17.45 ± 1.17	43.26 ± 2.44
10.0	26.85 ± 0.97	9.45 ± 1.22
15.0	24.58 ± 0.07	14.75 ± 0.90
20.0	20.76 ± 0.21	16.81 ± 0.72
25.0	25.42 ± 0.25	18.44 ± 1.21
30.0	14.36 ± 2.90	16.34 ± 1.21

7B: Riviera

Sample Depth/cm	Mn	Zn
5.0	16.40 ± 0.56	4.47 ± 0.20
10.0	31.19 ± 0.44	4.87 ± 0.24
15.0	30.05 ± 1.38	4.47 ± 0.42
20.0	26.27 ± 2.13	4.86 ± 1.33
25.0	43.31 ± 3.90	5.48 ± 1.35
30.0	22.86 ± 1.58	3.98 ± 0.33

7C: Sakumono

Sample Depth/cm	Mn	Zn
5.0	11.37 ± 1.64	6.92 ± 0.20
10.0	12.34 ± 1.47	5.92 ± 0.21
15.0	11.79 ± 1.06	4.42 ± 0.13
20.0	11.37 ± 1.52	9.39 ± 0.33
25.0	14.34 ± 1.06	4.95 ± 0.10
30.0	13.47 ± 0.26	6.98 ± 0.70

7D: Kpone

Sample Depth/cm	Mn	Zn
5.0	23.61 ± 0.54	5.51 ± 1.44
10.0	12.92 ± 3.24	3.97 ± 0.90
15.0	29.12 ± 1.31	4.44 ± 1.21
20.0	11.29 ± 1.06	4.42 ± 1.15
25.0	34.38 ± 0.28	4.45 ± 1.10
30.0	31.33 ± 0.56	4.99 ± 1.32

Trace metal levels in smaller aggregates of the sediments, with particle sizes less than 0.60 mm are higher than in the larger aggregates with particle sizes greater than 0.60 mm (Table 6) and (Figure 6). This agrees with the fact that adsorption of trace metals by sediments depends on the surface area of the sediments among other factors mentioned above[7]. Smaller aggregates have a larger surface area for adsorption than the larger aggregates. This also explains why experts or analytical chemists normally use particle sizes of 0.40 mm and below for most analysis involving sediments.

Table 7 shows the concentrations also in mg/kg measured at the various beaches at various depth. On the average, all the sediments contain substantial amounts of trace metals measured, especially Mn, elaborated clearly in Figure 7 and 8. Riviera registered the highest average concentration for Mn with Sakumono registering the least. Owene on the other hand registered the highest average value for Zn with Riviera and Kpone recording the least values. However, the concentrations are all lower than the values obtained by Okoye et al (1991) in Nigeria[12], and Kouadio and Trefry (1987) in Ivory Coast[13] for sediments from coastal lagoon in Nigeria and Ivory Coast respectively. Okoye in his publication reported of an anthropogenic heavy metal enrichment of Cd, Zn, Mn, Cu, Ni, Fe and Pb in the sediments of the Lagos lagoon and implicated land base urban and industrial waste sources.

Kouadio and Trefry in their studies of sediments from Ebrie lagoon reported of high concentrations of heavy metals including Zn and Mn in excess of background levels and this they attributed to the disposal of untreated sewage and industrial effluents.

The low levels of metals found in the Ghanaian beaches compared to the beaches of other West African countries like Nigeria and Ivory Coast, could be due to the high levels of industrialisation and its attendant urbanisation and other human activities along the coast of those countries as compared to that of Ghana. No direct relation between metal content and depth of sample has however been found.

CONCLUSION

Sediments from the same beach taken from different depths followed the same particle size distribution pattern, which differed from the distribution pattern at other beaches. Eastwards from Owene, particle sizes of sediments range from more coarse grains to finer grains at Riviera to a broad distribution of particle sizes at Sakumono and to medium grains at Kpone. It would be very helpful and important if this study is extended to cover the entire coast of Ghana and West Africa so that one would be able to tell the distribution pattern at any particular beach at a glance.

The levels of Mn and Zn in the sediments of our Ghanaian beaches are relatively low compared to the beached of other West African countries. All the same measures should be taken to maintain these levels and even bring it down to the barest minimum if possible.

SUMMARY

Sediments sampled at six different depths at four different beaches, Owene, Riviera, Sakumono and Kpone, were subjected to aggregate distribution and trace metal analyses for possible heavy metal pollution with relation to depth and particle size distribution of the intertidal sediments along the Accra-Tema coastal area. Open digestion commonly employed in the laboratory and closed digestion with Teflon bomb were used and the metals in the sediments were determined by Atomic Absorption Spectrophotometer (AAS). Results indicate that sediments from the same beach taken from different depths follow the same particle size distribution pattern which is different from distribution patterns shown by the other beaches. Eastwards along the coast from Owene, particle size of sediments, irrespective of depth, moves from more coarse particles to very fine grains at Riviera, then to broader distribution of particles at Sakumono and to medium grains at Kpone. Digestion with the Teflon bomb was found to be more efficient and better than the open digestion method.

Fine grains of sediments with particle sizes of 0.40 mm and below were found to contain higher levels of the metals than the coarser sediments with particle size greater than 0.40 mm, however, no direct relation between metal content and depth of sample has been found. All the sediments were found to contain on average, high amounts of metals especially manganese but the concentrations were all lower than the values obtained by other researchers for sediments from coastal waters of Western and Central Africa.

ACKNOWLEDGEMENT

FIG. 1   THE STUDY AREA AND SAMPLING SITES

COASTAL MAP FROM OWENE TO KPONE
SHOWING SAMPLING AREAS

A MAP OF GHANA SHOWING
THE LOCATION OF THE STUDY
AREA

STUDY AREA

Tema
Accra

Tema   KPONE
SAKUMONO
INDEPENDENCE SQUARE
ACCRA
OWENE
Chorkor

LEGEND

Sampling Points

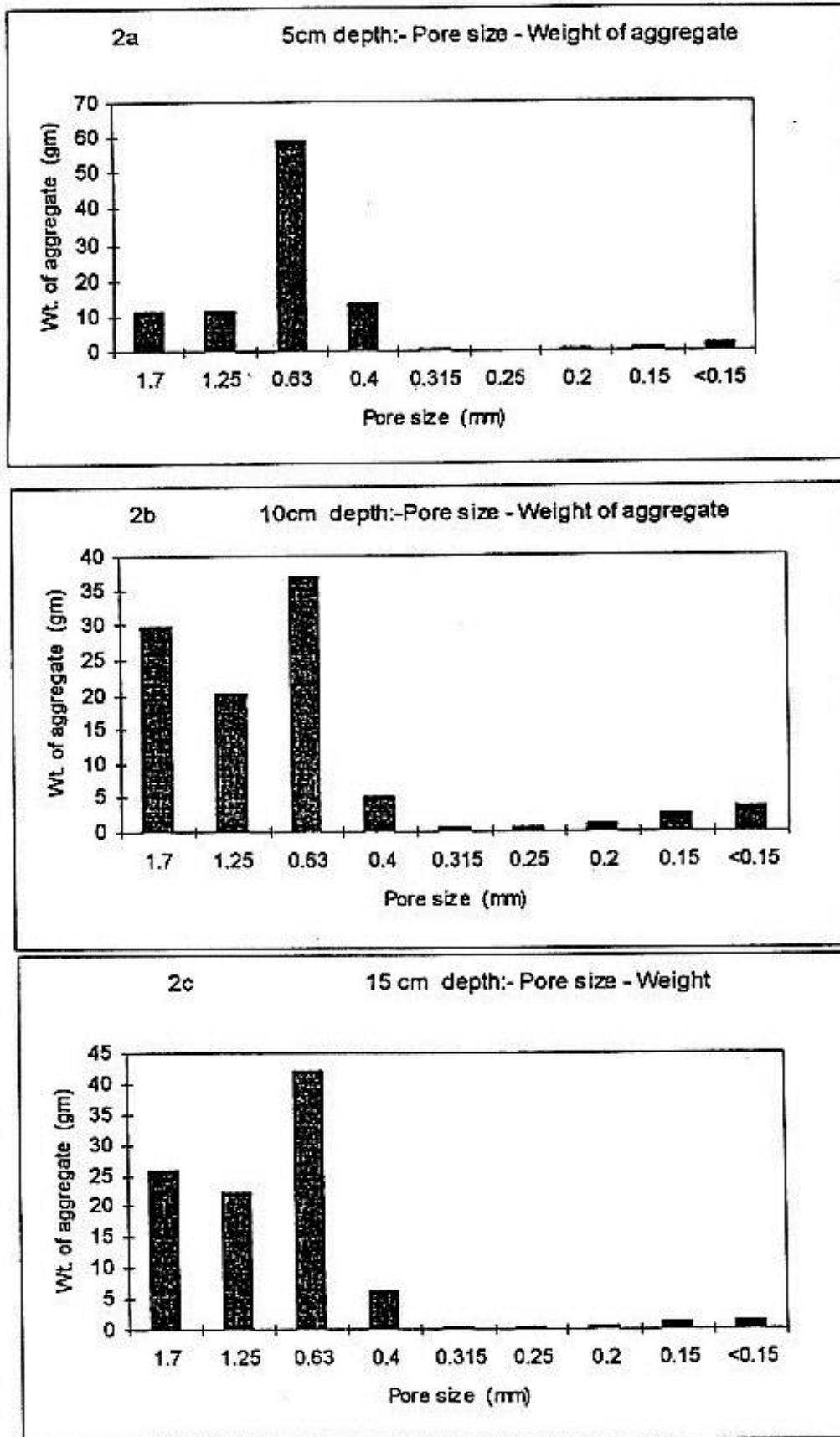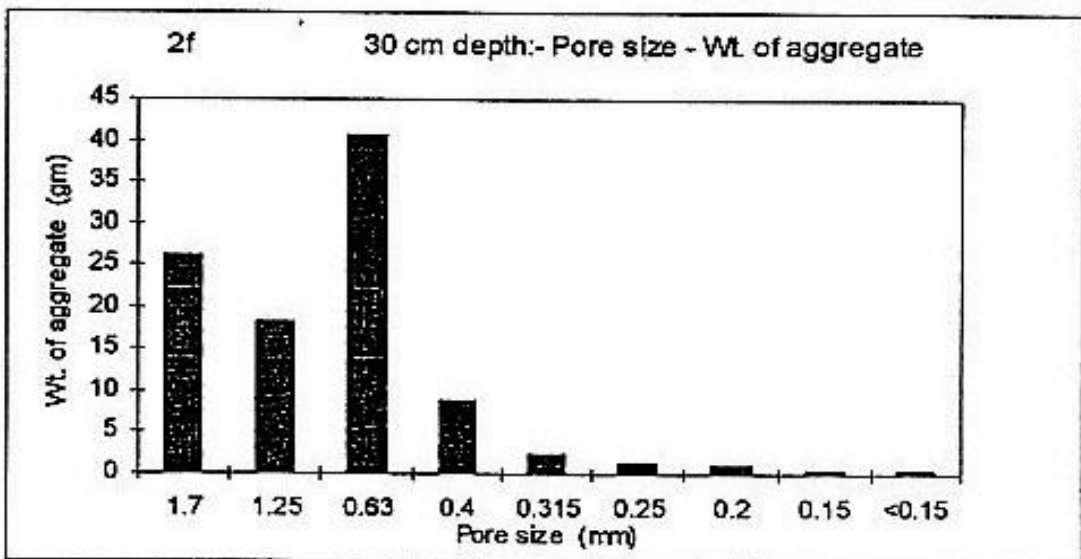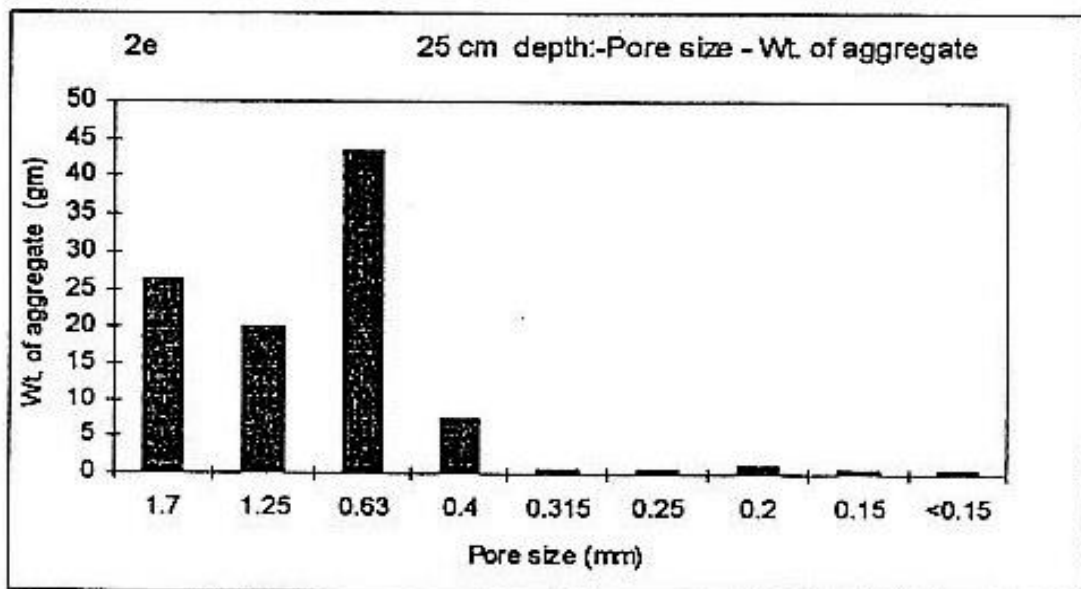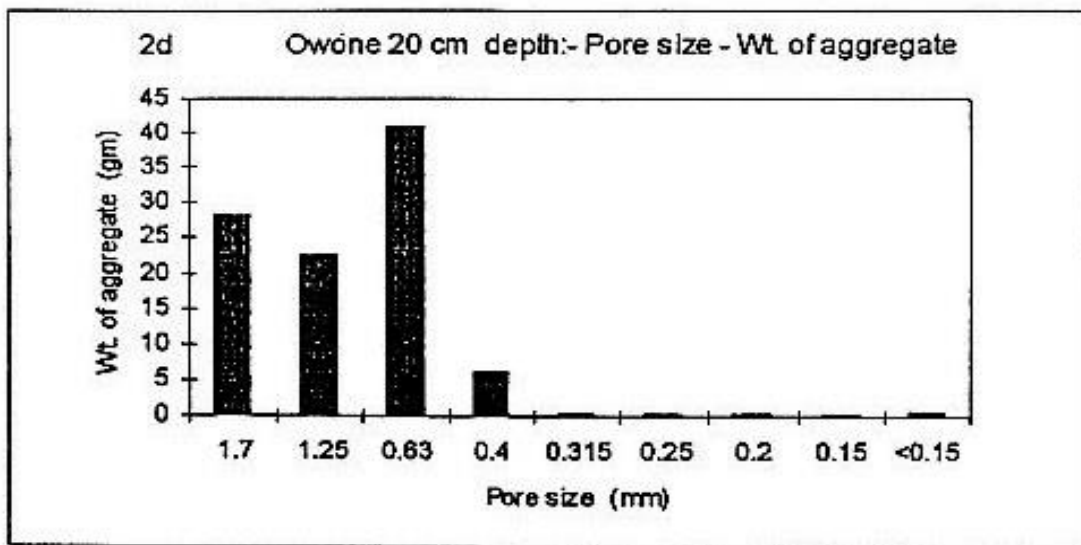Sampling Areas

0   20   40 KM.
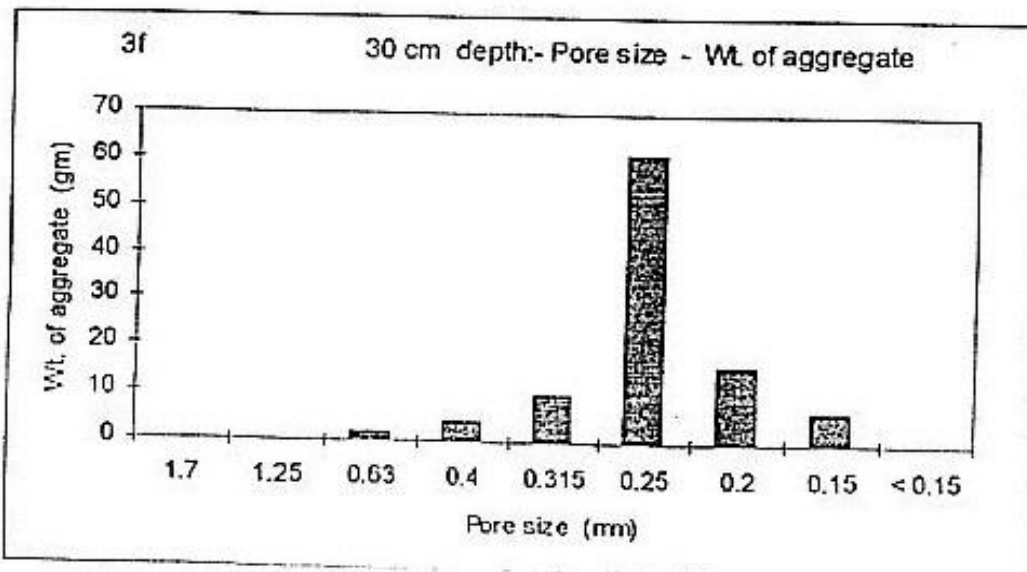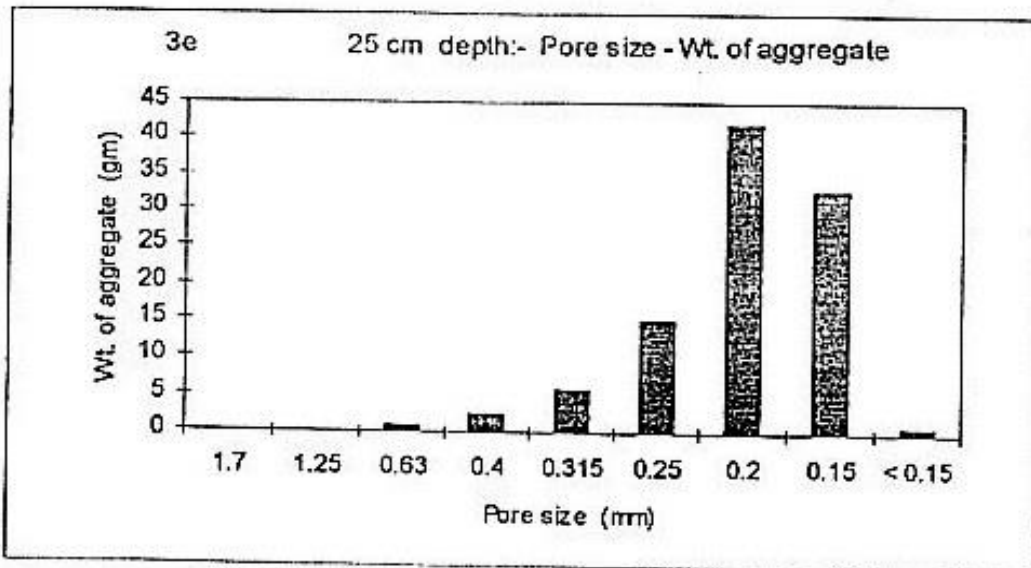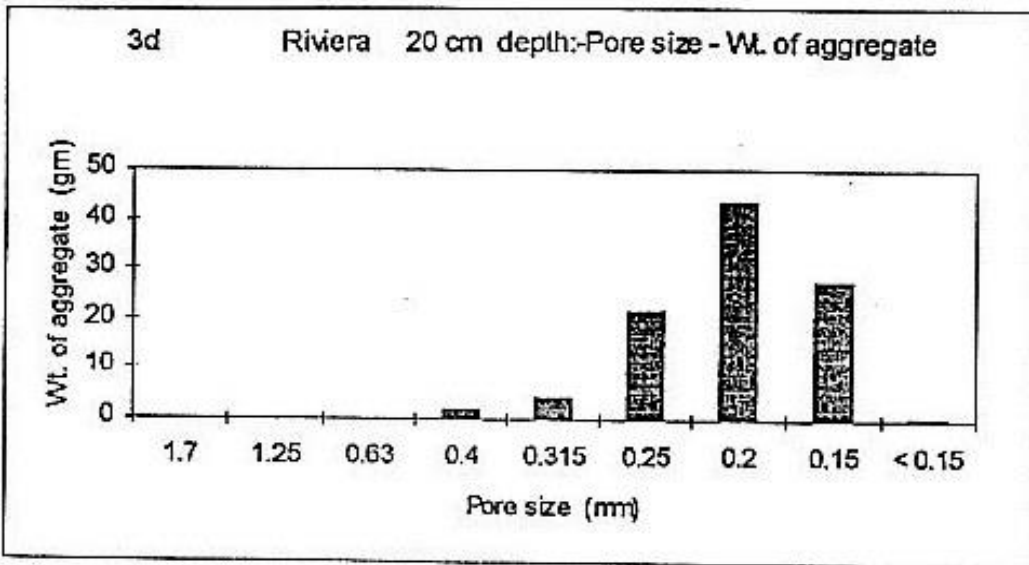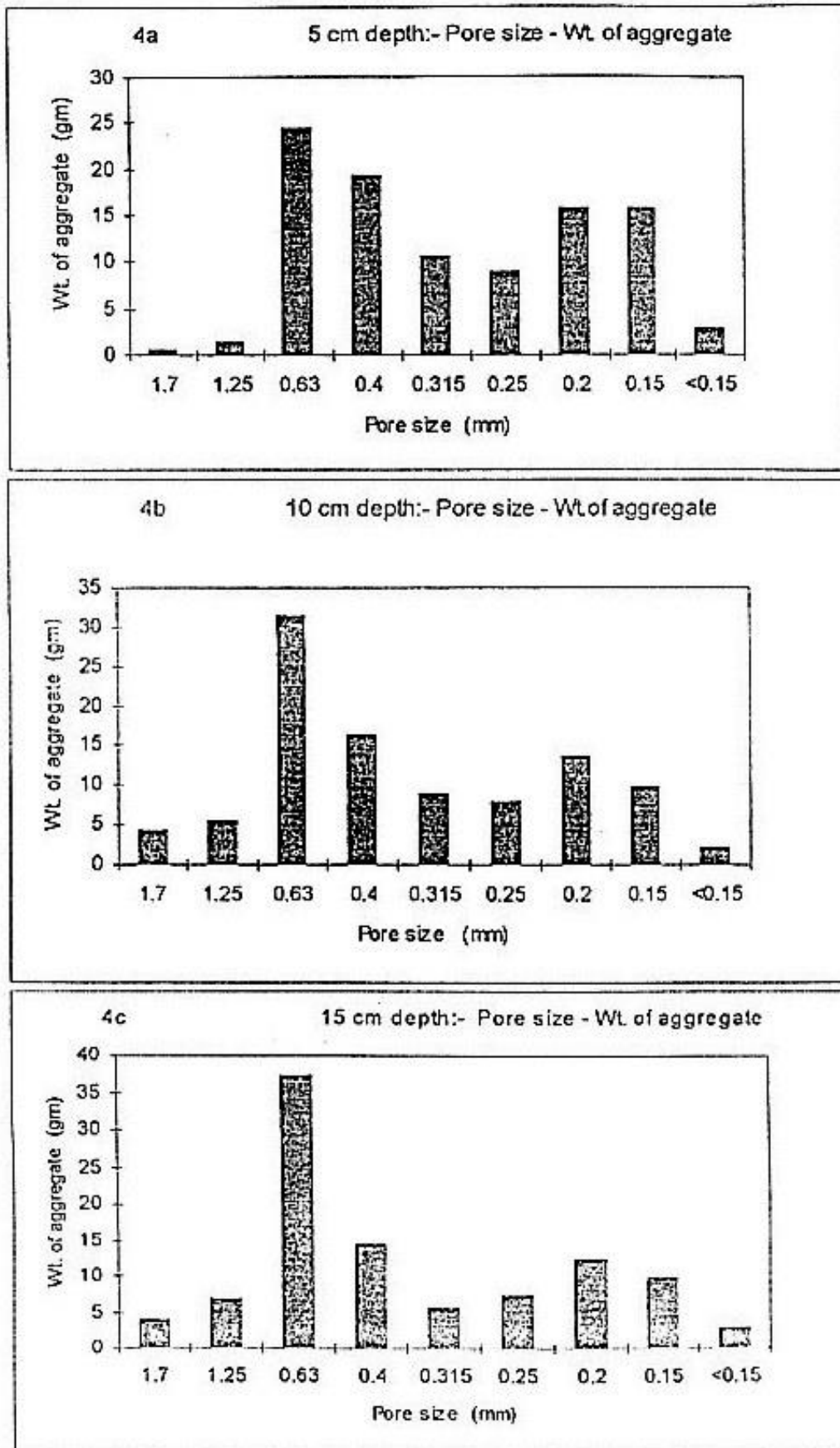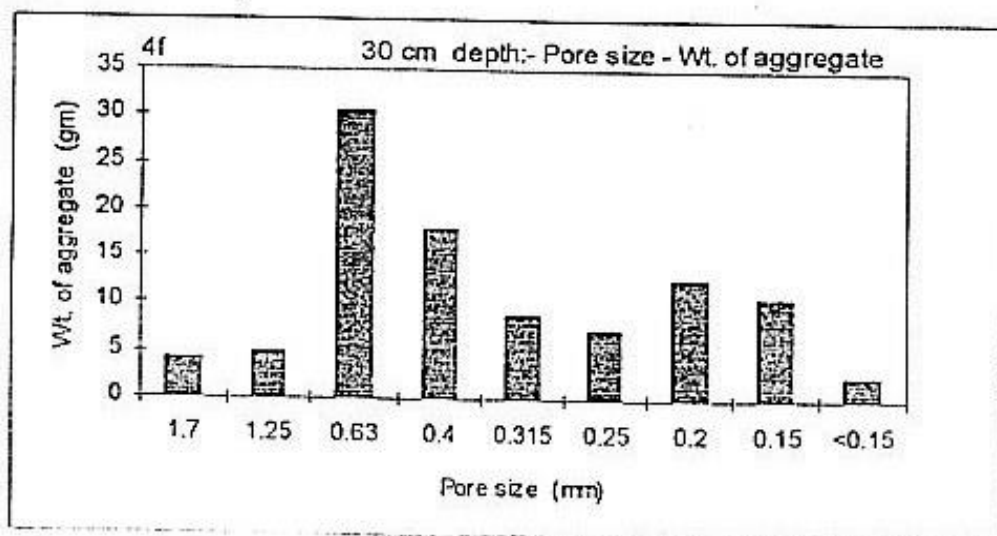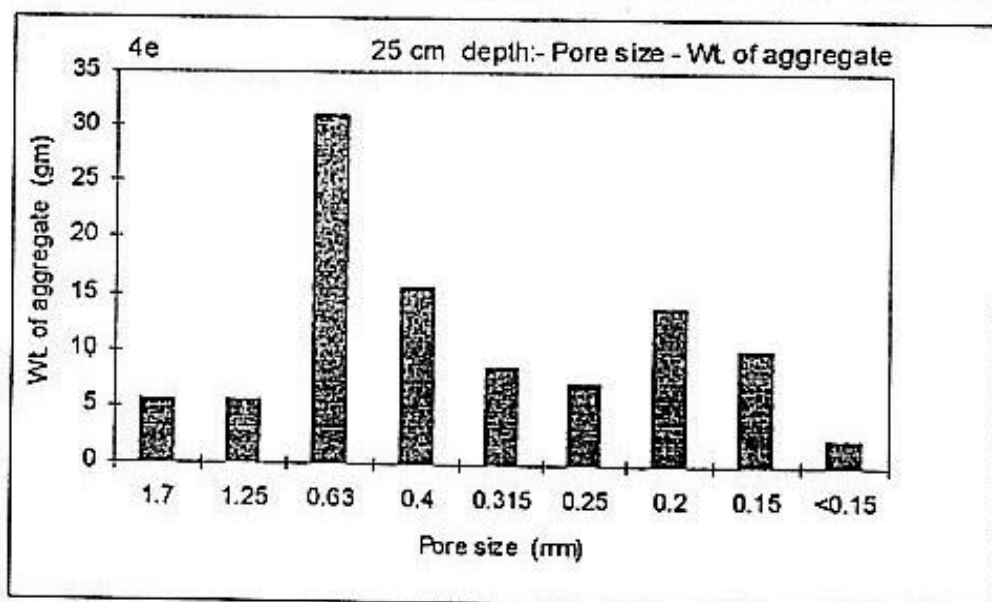
0° 00

0° 30' W.

5° 00' N

6° 00' N
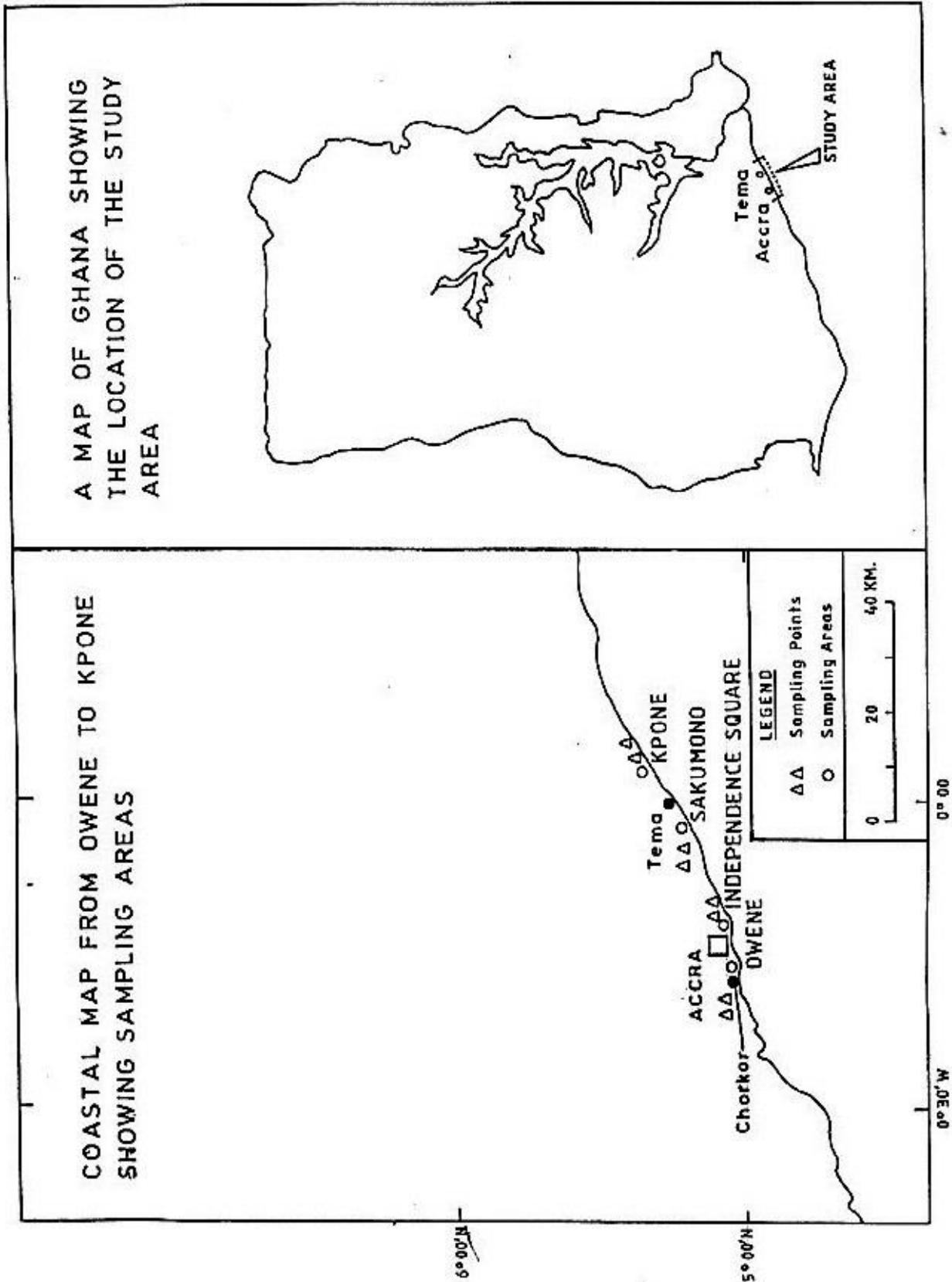
Fig.2   Aggregate Size Distribution at Owene.

2a   5cm depth:- Pore size - Weight of aggregate

2b   10cm depth:-Pore size - Weight of aggregate

2c   15 cm depth:- Pore size - Weight

2d Owóne 20 cm depth:- Pore size - Wt. of aggregate

2e 25 cm depth:-Pore size - Wt. of aggregate

2f 30 cm depth:- Pore size - Wt. of aggregate

3d   Riviera   20 cm depth:-Pore size - Wt. of aggregate

3e   25 cm depth:- Pore size - Wt. of aggregate

3f   30 cm depth:- Pore size - Wt. of aggregate

Fig.4   Aggregate Size Distribution at Sakumono.
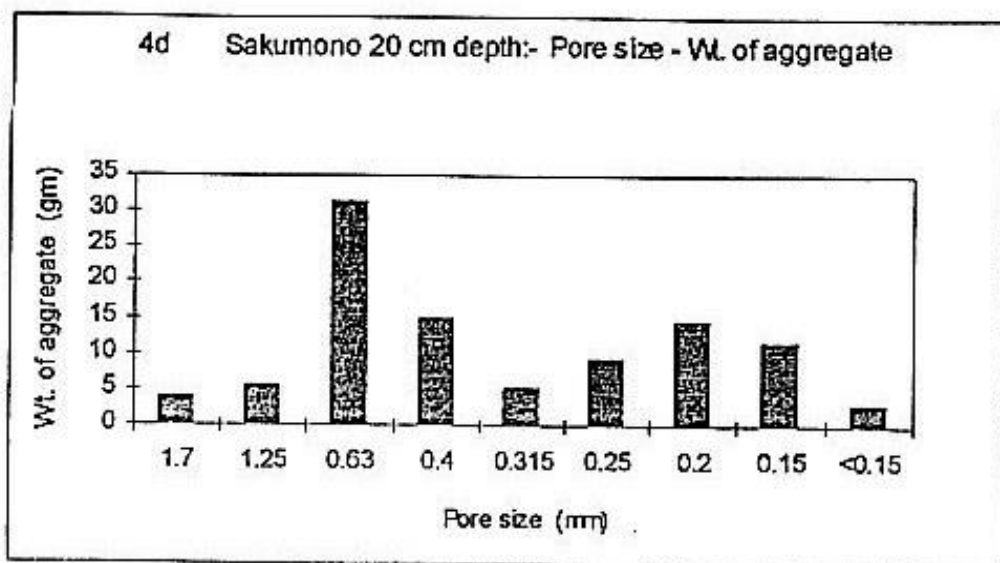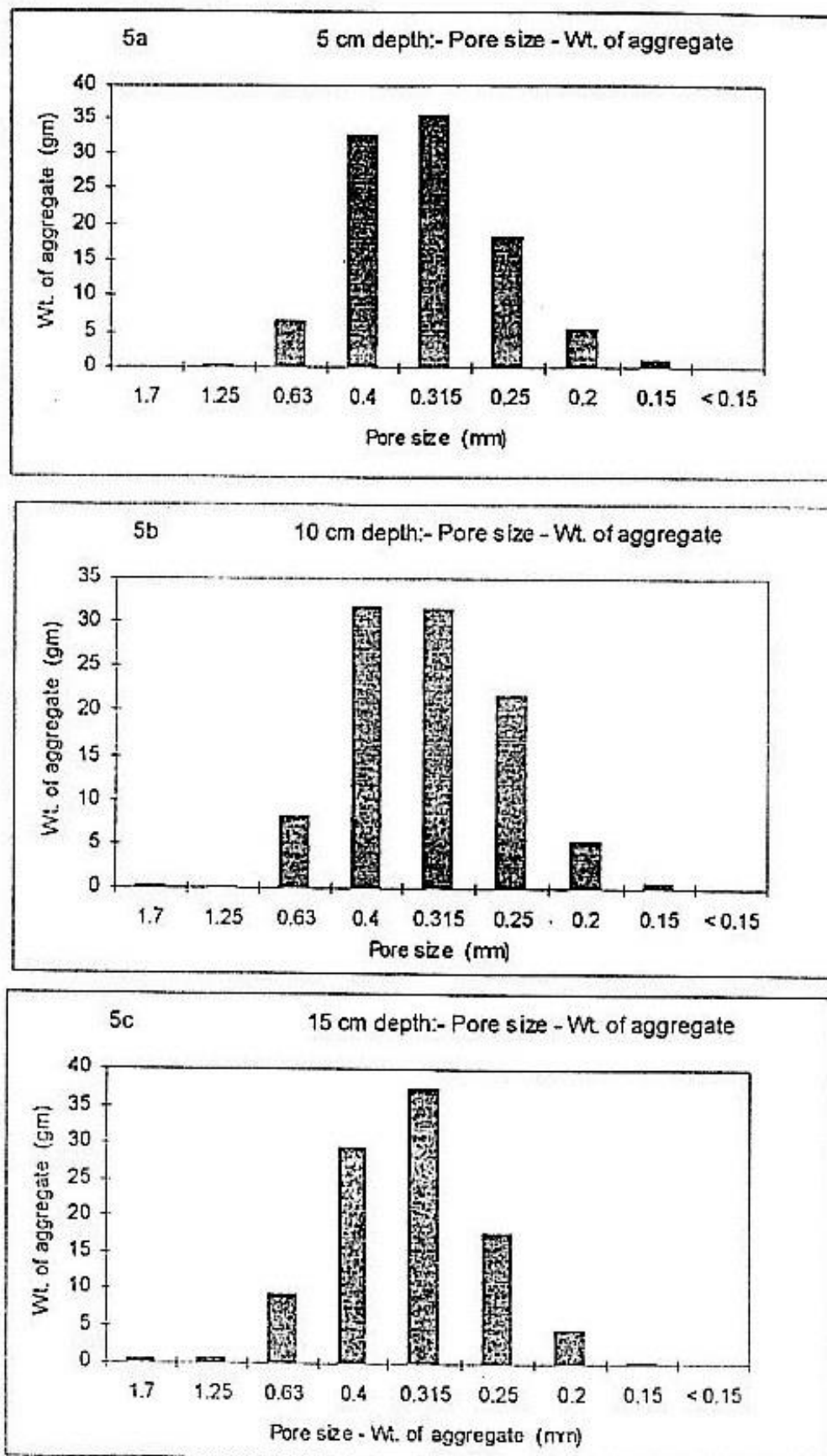

4a   5 cm depth:- Pore size - Wt. of aggregate

4b   10 cm depth:- Pore size - Wt. of aggregate

4c   15 cm depth:- Pore size - Wt. of aggregate

4d Sakumono 20 cm depth:- Pore size - Wt. of aggregate

4e 25 cm depth:- Pore size - Wt. of aggregate

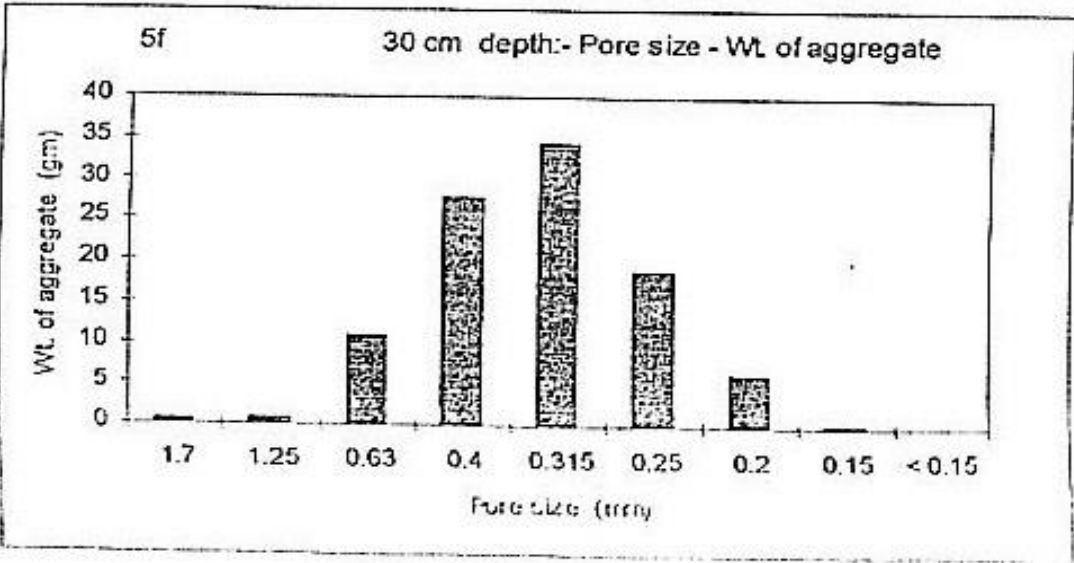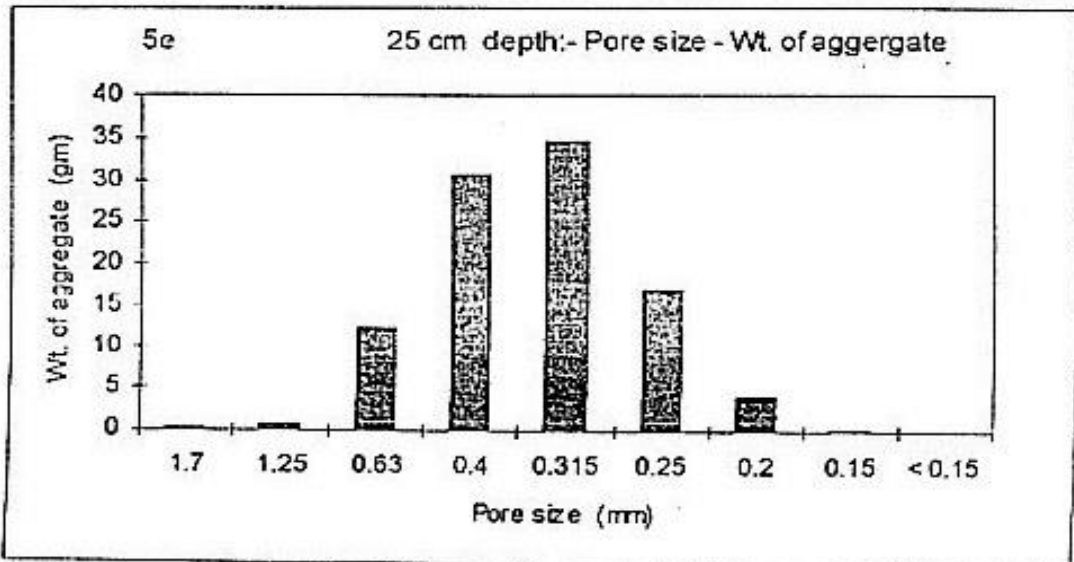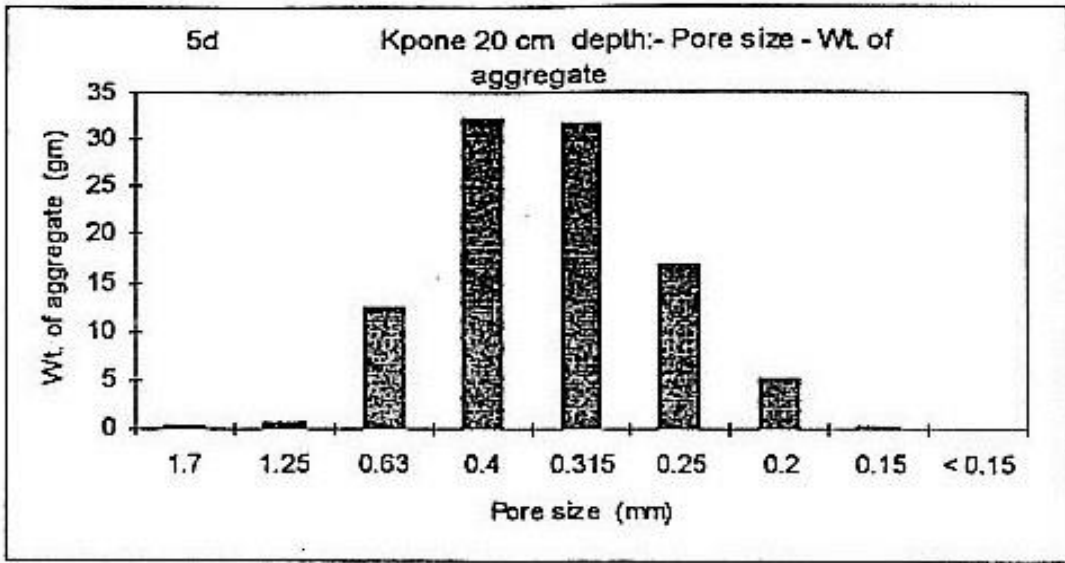4f 30 cm depth:- Pore size - Wt. of aggregate

Fig. 5   Aggregate Size Distribution at Kpone

5a   5 cm depth:- Pore size - Wt. of aggregate

5b   10 cm depth:- Pore size - Wt. of aggregate

5c   15 cm depth:- Pore size - Wt. of aggregate

5d   Kpone 20 cm depth:- Pore size - Wt. of aggregate

5e   25 cm depth:- Pore size - Wt. of aggergate

5f   30 cm depth:- Pore size - Wt of aggregate

Fig. 6   A Graph of Concentrations of Trace metals Adsorbed by the Different Particle Sizes of Sediments at Sakumono

Concentration/ppm

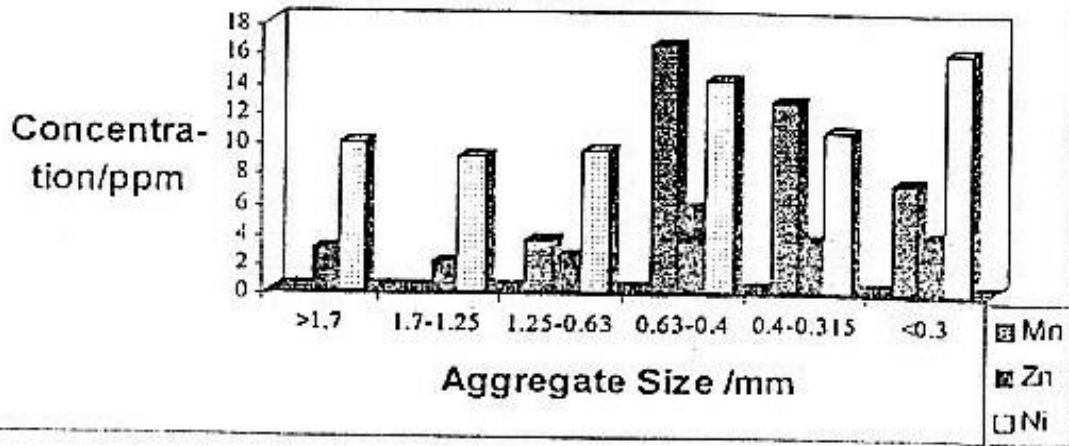Aggregate Size /mm

>1.7   1.7-1.25   1.25-0.63   0.63-0.4   0.4-0.315   <0.3

Mn
Zn
Ni

Fig. 7   A Graph of Concentration of Mn and Zn Metals Along the Various Beaches at 20cm Depth.

Concentration

Owene   Riviera   Sakumono   Kpone

Beach

Mn
Zn

Fig. 8   A Graph of Concentration of Mn and Zn Metals Along the Various Beaches at 20cm Depth.

Concentration /ppm

Owene   Riviera   Sakumono   Kpone

Beach

Mn
Zn
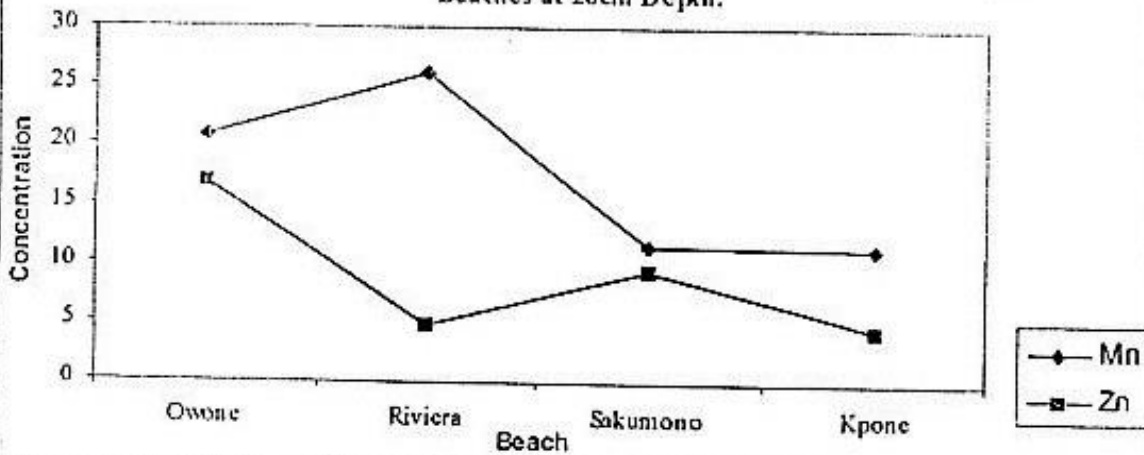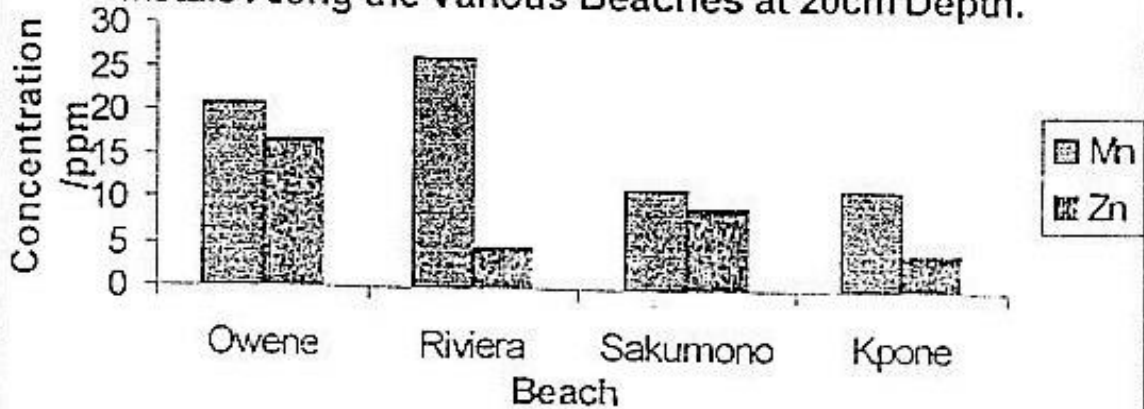
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