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Sediment Sources, Redistribution, and Management in Ekpoma, Nigeria

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ABSTRACT Ekpoma is a town in which there is a great deal of construction work currently taking place. Vast amount of sand and gravel are transported from the suburbs into the town daily. Lack of planning has led to misuse of the land, the consequent of which is sediment redistribution. Road surfaces and drains have become buried and blocked with sediment. There appears to be a fundamental conflict between the natural drainage network and the artificial drainage system as well. Over 90 percent of Ekpoma populace are aware of the sediment problem, but they have not, as yet, urged any action, probably because the consequences of sediment and deposition are comparatively less disastrous than other natural hazards. However, general street maintenance is increasingly becoming impossible and there is a general deterioration of the town environment leading to serious traffic accidents, especially at T-junctions. This paper examines some of the sources and causes of the sediment and proposes possible solutions to the problem.

INTRODUCTION

The problem of sediment is all pervading. The all-pervading nature of the problem attracted the attention of investigators through the ages. As recognized by Sanmuganathan (1990, p.5), it makes its presence felt in all aspects of Civil Engineering Hydraulics. Coastal engineers are not immune form it; they are concerned with beach erosion, littoral drift among others. Tidal engineers worry about siltation of navigation channels and mud banks, River engineers are concerned with river morphology and the changes in riverbed elevations brought about by structures. Sediment problems have both economic and social dimensions (Akintola, 1978).

Currently, Nigeria cities are experiencing rapid spatial expansion manifested by the construction industry (Oyegun, 1987). This is revealed in the number of building projects going on in various cities. Every now and then lorries are seen carrying gravel, sand and laterite from the suburbs to the cities. In many locations within the cities one could observe water pipes being laid, poles and masts for electricity, telephone, and television are being erected as well. In the same vein, underground cables for electricity and telephones are equally being laid. Earth roads are being graded. The consequence of all these construction activities is that a greater part of the soil is disturbed. As is always the case, a substantial proportion of these disturbed soils and loose sands generated find their way into the cities drainage system during heavy rainfall.

Before 1976 Ekpoma was characteristically rural with isolated settlements, few houses, health, educational, commercial and transportation facilities (Olomo, 1991). Roads were untarred and were mainly minor roads and footpaths (Ojeifo, 2000). Since 1976 when Ekpoma was made a Local Government Headquarter, it has grown into an urban center. The location of Edo State University (previously called Bendel State University), and other major investments have taken place in Ekpoma. These investments, to a great extent, have propelled growth in population, socio-economic activities, employment, physical growth and expansion in the area. For instance, while the population of Ekpoma was 13,036 by 1975, it rose to 45,488 in 1991 (National Population Commission, Ekpoma, 1992) with only 8.62km^2 of the total 62km^2 of land area used for physical growth in 1979 (Olomo, 1991; Ufuah, 1993), physical growth and expansion have increased to 29.28km^2 by 2003 with residential, transportation, commercial, industrial and other land uses. For example, with less than 8 places of religious worship in 1976, the area as 2003 has over 50 worship centers (Ojeifo, 2003). Roads development has increase steadily over the years from 12.3km of untarred road in 1975 to more than 86.3km (Olomo, 1991). About 98% of the tarred roads were done between 1980 and 1983. Drainage networks in Ekpoma were constructed about the same period to carry away surface water. However, since that date, building activities have

developed enormously without a corresponding change in the drainage network. The result is that the drains can no longer accommodate storm runoff and excess runoff spills over the adjoining roads.

Urbanization has been known to cause four interrelated effects on the urban hydrological regime. (Odemerho and Sada, 1984; Oyegun, 1987; Aziegbe, 1991). These are:

- peak flow characteristics
- total runoff
- the quality of the water
- the hydrologic structures or amenities

With the ever-increasing intent and desire to develop, more housing and other socio-economic activities are springing up in Ekpoma. The consequences of all these ill-conceived construction schemes are changes in the facets of hydrological cycle.

Leopold (1974) specified two factors that govern such flow regimes as: (1) the percentage area made impervious and (2) the rate at which water is transmitted across the land and stream channels. Where urbanization is intense, especially on flood plains, the hydrographs often show bursts on the rising limbs, and runoff is instantaneous. Figure 1 exemplifies the flood hydrograph associated with a city in which rapid urban expansion has occurred as observed in Ekpoma, in September 2004. The several bursts on the rising limb of the hydrograph are a reflection of the nature of tropical seasonal rainfall. Since roofs cover the floodplain and concrete structures in most places, runoff from such rain bursts are almost instantaneous. Total runoff is increased as more area is given over to concrete. Even when an area is not covered by roof or concrete, it will yield a rapid runoff if it is impermeable and most untarred surfaces in Ekpoma are of this nature. Their impermeability inhabits infiltration of water into the ground; so that most of the rain falling on them contributes to the total runoff.

THE STUDY AREA

The study area is Ekpoma, the administrative headquarters of Esan West Local Government Area of Edo State, Nigeria. The area proper lies between latitudes $6^0 43'$ and $6^0 45'$ North of the Equator, and longitudes $6^0 6'$ and $6^0 8'$ East of the Greenwich Meridian (Fig. 2a, b and c). Ekpoma is made up of many quarters including Eguare, Iruekpen Emaudo, Ujoelen, Ihumudumu, Illeh,

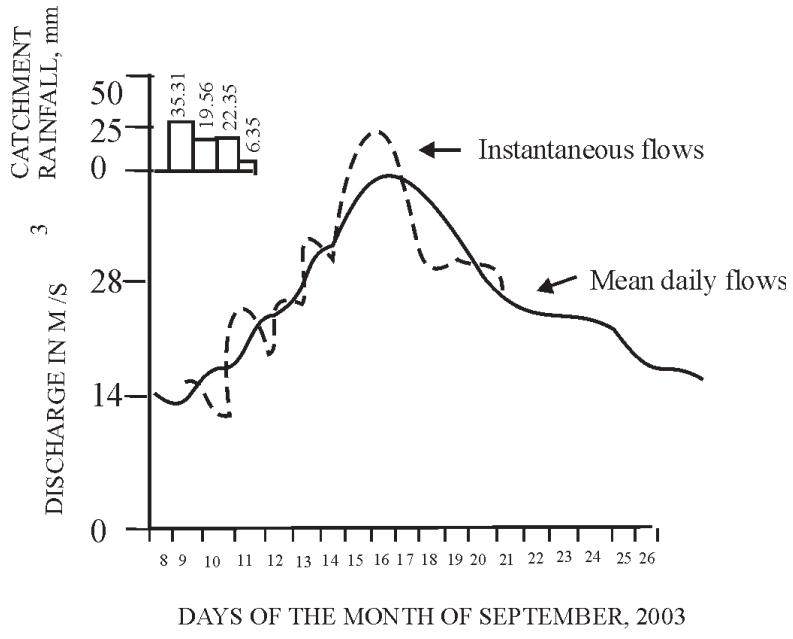

Fig. 1. An example of a slow Rising Flood a Ambrose Alli University Station

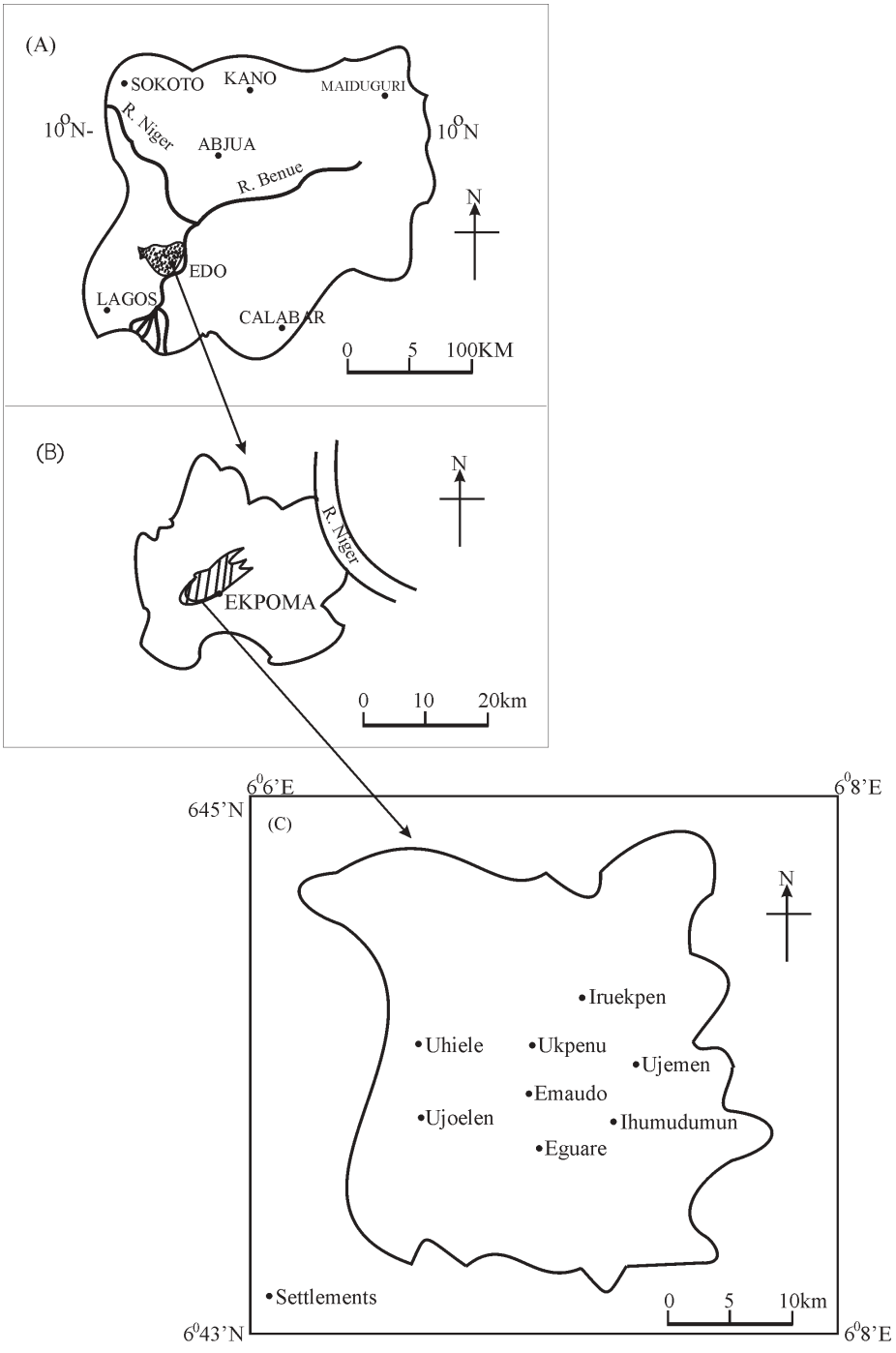

Fig. 2. A: Map of Nigeria showing Edo State
B: Map of Edo State showing Ekpoma
C: Map of Ekpoma showing some major settlements

Uke, Uhiele, Ujemen, Ukepnu, Idoa, Ukhun, Egoro, Emuhi, Igor and Idumebo. These quarters are all considered in this study. Ekpoma experiences the humid tropical climate classified as A_w using the Köppen climatic classification scheme. The annual rainfall in the area exceeds 2000mm (Ogunkunle et al, 1980) with a bimodal distribution. The first peak occurs in July with monthly precipitation of 344.7mm and the second in September with 457.2mm (Aziegbe, 2003). Most of the storms are convective outburst and they have short-term intensities. The highest mean monthly temperature of 291.1°C is recorded in March and the lowest of 24.4°C in June. The soils have been classified as ferallitic, being highly weathered, leached and having high proportion of kaolinite and free iron oxide, but generally without a lateritic iron pan layer (Areola, 1990). According to the Nigerian soil map, prepared by the Federal Survey (1967), the soil type can be categorized as feral soils on loose sandy sediments. The topography is undulating which has given the advantage to easy construction and connectivity of roads.

The Sediment Problem in Ekpoma

Sediments for the whole of the rainy season usually cover many of the tarred roads in Ekpoma and, for a considerable part of the dry season (Fig.3). Samples for sheet-wash have been collected and analyzed. It revealed that sediment concentration could be as much as between 720mg/l and 4,100mg/l and, with an annual rainfall exceeding 2000mm, the amount of sediment that can be moved on the ground surface in Ekpoma is considerable. This leads to several problems, among which are:

1. Blocking of artificial and natural drainage ways
2. Drainage to city highways
3. Traffic accidents after rainfall
4. Flash flood incidence
5. Increase in cost and frequency of street maintenance
6. General deterioration of the urban environment
7. Increase in water treatment cost for both domestic and industrial uses.

Study Objectives

Previous pertinent studies have failed to give consideration to the problem of sediment sources and redistribution in Ekpoma (Olomo 1991; Ufuah 1993; Ojeifoh 2001, 2003). This represents the focus of the study. Besides, sediment deposition studies in urban settings should aim at enabling people to recognize the problem, document causes of erosion, indicate sources and zones of deposition, and also, suggest solutions for reducing the problem. Apart from indicating that sediment deposition on roads constitutes an environmental hazard in Ekpoma, the objectives of the study included an attempted identification of the sources and depositional zones of the sediments. It examines further, the main factors and mechanisms of sediment production in the town, sediment concentration in runoff during rainstorms, and the people's perception of the sediment problem.

METHODOLOGICAL APPROACH AND DATA COLLECTION

Two approaches were adopted in this study. They involve reconnaissance survey and direct measurements of Ekpoma town. The purpose of the survey was to identify zones of sediment concentration and the amount of accumulation. Zones of sediment concentration are areas on the tarred roads whose entire width is covered by loose soils. These loose material range from silt to gravels and pebbles in grain size. Should a street be so covered by sediment throughout its entire length, such a street is regarded as 'sediment polluted'. Based on this working definition, 16 streets were regarded as polluted. These streets vary in length from 0.1 to 3.0km (Fig. 3).

Measurements were also made of street width. The width of loose soils deposited on each side of the street was measured, so that the percentage of each street covered by loose sediments can be obtained. Traffic density of the streets was estimated to find out if relationship exists between the degree of 'sediment pollution' and traffic density.

Land use Mapping

Consequent upon urbanization, more areas are covered by roofs or concrete, such roofs and concrete become additional contributing areas to total runoff. There is, therefore, a gradual increase of storm runoff as urbanization increases.

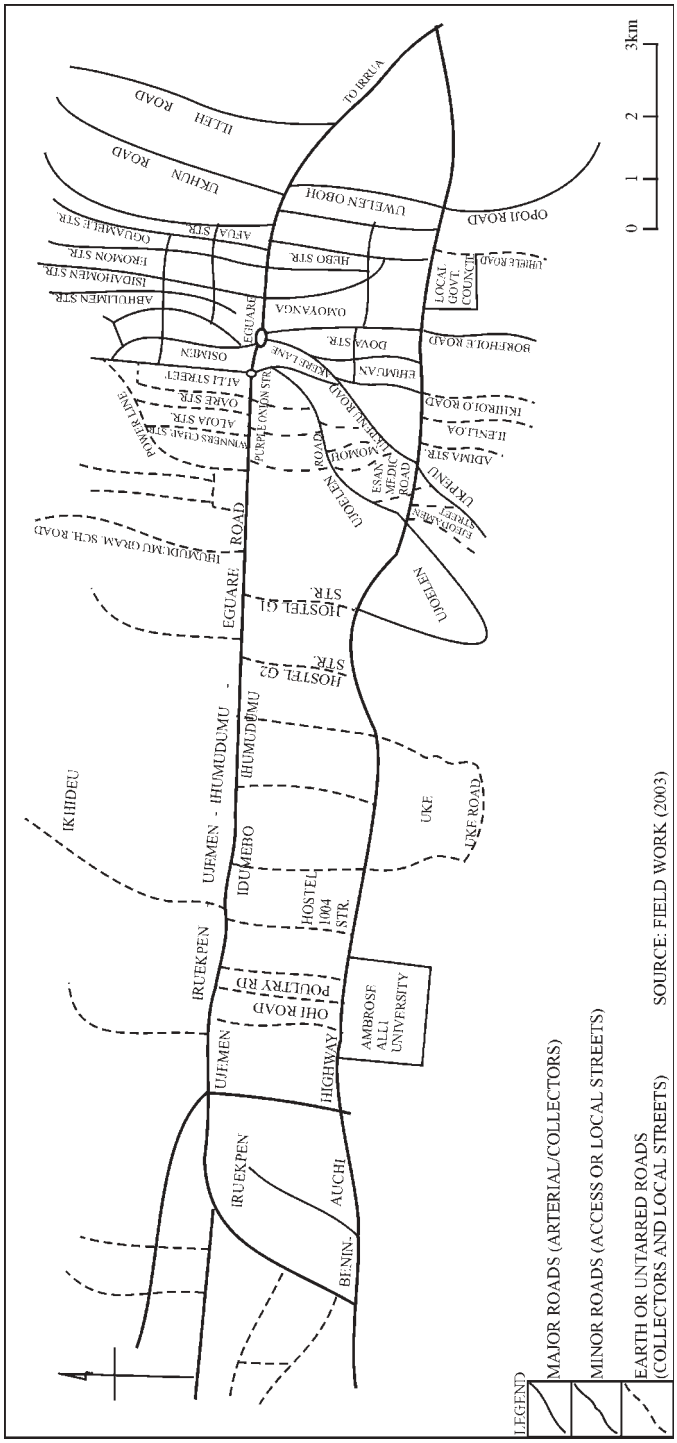

Fig. 3. Ekpoma showing the road layout as at 2003.

Since 1976, when Ekpoma was made a Local Government Headquarter, there have been marked changes in the land use, the estimates of land use changes were obtained from photo-mozaics of the town, for years 1963, 1973 and 1982 at a scale of 1:6000. Ground investigation was carried out to have insight into what is obtainable at present.

Surface Water Flow Mapping: The direction of surface water movement was mapped after rainfall in this study. Measurements were made of the sizes of the drainage channels. The number of culverts, if any, and their condition were observed and recorded in the field.

Sediment Hazard Perception Survey: Two hundred and fifty questionnaire were administered in order to test people's perception of 'sediment pollution'. 'Sediment pollution' becomes a hazard in this study when it; hinders mobility of traffic; results in flooding, is an environmental blight, and/or constitutes health problems. Different respondents perceived the problem in different ways. The questionnaire survey was randomly executed over the entire town.

RESULTS

Some of the causes of sediment problems in Ekpoma as observed include the following:

Blocked or Inadequate Drains: Blocked culverts and a complete absence of side drains along the streets are factors responsible for 'sediment pollution' of Ekpoma streets. During this survey, it was observed that 25 out of the 50 culverts along one side of Royal Market Road were blocked. Similar situations existed for other roads. Table 1 shows the widths and the proportion covered by sediment. The table also shows the size of the side gutters and the situation they were during this study.

Bare Surfaces: In conjunction with the numerous construction sites, bare surfaces that occur in private compounds; untarred roads; road 'islands' and sidewalks are sources of sediments. Road 'islands' are common in the dual carriageways. These 'islands' comprised of bare soil, which in virtually all cases, are easily washed into the road during heavy rains.

Poor Road Alignment Across the Terrain: In majority of the observed cases, runoff flow convergences occur on roads. In other words, sediment-laden water flowing in opposite directions on the road surfaces (because of the absence of gutters, and/or blockage of available ones) meet, resulting in turbulence and deposition. This phenomenon is responsible for the sediment concentration at one spot along the Ekpoma section of the Benin-Auchi Expressway (precisely at Moscow junction). A section of the road here slopes S. W. at about 6 degrees. The other section is more or less flat, but slopes N. E. for the first 87 meters. The road junction here is a major sediment concentration zone. It is a very serious traffic hazard zone particularly during the rainy season (Fig. 4a, b, c and d).

Road Curvature: Water and sediment flowing on the road surfaces will not follow road curvature. Instead, it flows along the road seeking the shortest distance to a main channel, at a lower elevation. This is essentially true in the absence of a drainage channel to direct the flow. The road curvature at the front of the Royal Highness compound, along Royal Market Road exemplifies this, and is another sediment concentration zone (Fig. 4a, b, c and d).

Table 1: Sample point estimate of road width covered by sediment

Road	*Road width (m)*	*Width (m)*	*Covered (%)*	*Gutter dimension (cm)*
Benin-Auchi	24	24	100	None
(4 sample points)	24	22	91.7	None
	24	24	100	None
	24	23	95.8	None
Royal Market Road	18	15	83.3	90 x 92 (blocked)
(2 sample points)	18	13	72.2	64 x 71 (blocked)
Ihumudumu	18	18	100	66 x 62 (blocked)
(2 sample points)	18	16	88.9	60 x 60 (blocked)
Ujemen	18	17	94.4	None
(2 sample points)	18	14	77.8	None
Ujoelen	13	12	92.3	None
(2 sample points)	13	9	69.2	None
Ukhun	10	8	80	None
Borehole	9	5	55.6	None
Uke	9	3	30	None
Ukpenu	13	13	100	None
Poultry	9	6	66.6	None
Uke	5	3	60	None
Dova	10	8	80	31 x 37 (blocked)
Ikhirolo	18	9	50.6	None

Source: Fieldwork 2004

Cross Current of Sheet Wash: This is a common feature at roundabouts and at T-junctions of gutters and roads particularly when the gutters are blocked. As with the case, when surface water moving in opposite directions or at acute angles meet, it results in increased turbulence and deposition. This is the case with Opoji junction and One Thousand and Four junctions. Sediment fans usually occur at such T-junctions in Ekpoma. This type of situation causes most of the sediment hazard zones along the Ekpoma section of the Benin-Auchi Expressway (Fig. 4a, b, c, and d).

Inadequate Manpower and Equipment: Lack of sufficient personnel and equipment is one major problem facing the clearing of sediment from Ekpoma streets. The Local Government, which is now responsible for clearing the town, having taken over the responsibility from the Ministry of Housing and Environment, inherited grossly inadequate equipment.

At present, the Government is vigorously pre-occupied with the disposal of solid wastes (excluding sediments). By this, it implied that the government's equipment and personnel are deployed to clear refuse from the 42 'dumpsters' located at various strategic positions. The implication of this is that neither personnel nor equipment is spared to take care of the town's sediment dumps, especially when sediment concentrations on the streets are not regarded as a health hazard (see Tables 2 and 3).

Table 2: Equipment for environmental sanitation in Ekpoma as at August 2004

Equipment	*Quantity*
Cesspool Emptier	1
Covered refuse lorries	5
Tipper lorries (Govt. owned)	3
Tipper lorries (hired)	5
Pay loader	3
Rake with long handle	40
Shovels	50
Wheelbarrows	36
Brushes with long handle	23
Fork – diggers	20
Head pans	21
Sanitary domestic dustbins	11

Source: Fieldwork 2004

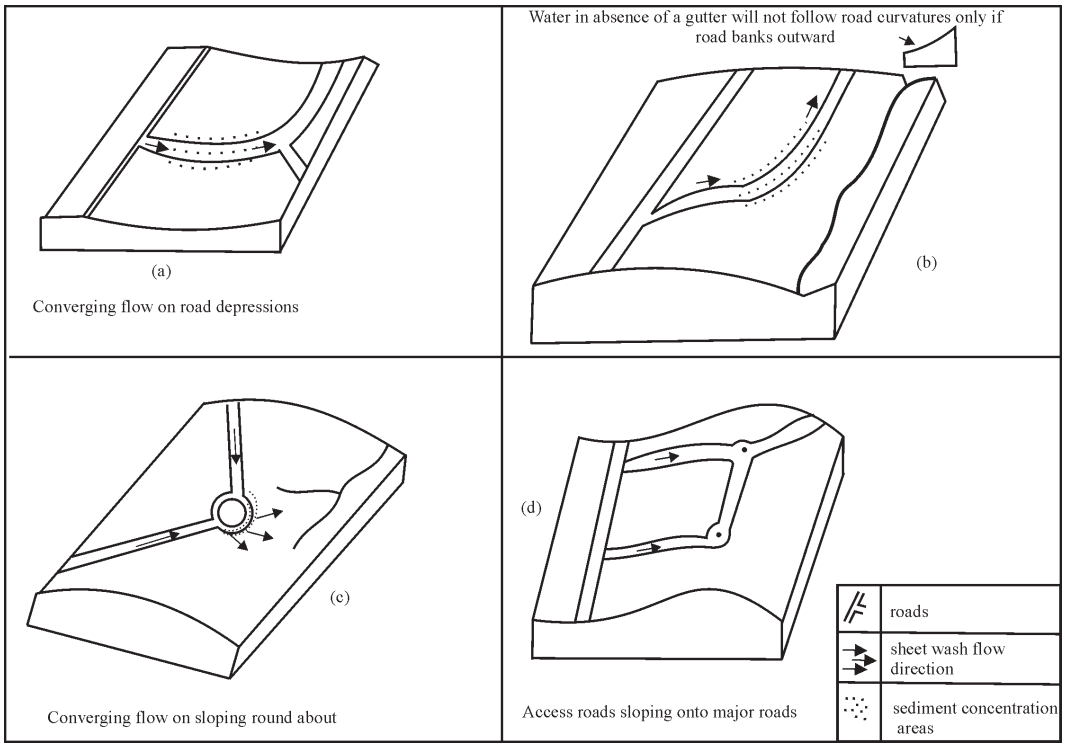

Fig. 4. Topography, roadnetwork, sheetwash flow direction and sediment hazard areas in Ekpoma.

Table 3: Personnel for environmental sanitation in Ekpoma

Positions	*Numbers*
Principal health superintendent	1
Senior health superintendent	2
Higher health superintendent	4
Public health superintendent	7
Health attendants	10
Drivers	3

Source: Fieldwork 2004

Road Traffic: It was observed in this study that heavy traffic in conjunction with heavy rainfall leads to quick deterioration of roads. For example, available statistics from the Ministry of Works and Transport show that since 1976 there has been a steady rise in the number of vehicles registered in Ekpoma. It has risen from a mere 80 in 1976 to, 1000 in 2003 representing an annual growth rate of about 20 percent. On 3 of the most 'sediment polluted' streets, traffic flow was found to range from between $80/hr^{1}$ (along Eguare-Ihumidumu road) to $150/hr^{-1}$ (on Ujoelen road). The heavily used roads deteriorate faster as manifested in terms of portholes. These portholes are sources of sediments since they are exposed to direct impact of raindrop and splash erosion. They also serve as surface storage for storm runoff. Often when these potholes are repaired, they are simply filled with soil. The soil is dislodged by constant traffic usage and washed back unto the road surface during subsequent rains.

Land use Changes in Ekpoma: Land use change in Ekpoma between 1963 and 1982 can be appreciated better using two quarters in the area. These are Eguare and Ujoelen quarters.

The result of land use in Ujoelen quarters for instance, show that the areas made impermeable by concrete or roads have increased steadily from 50.33 percent in 1963m to 88.48 percent in 1982 (Table 4). Within the same period, the bare surfaces, grassed areas and forests have decreased steadily, giving way to houses, roads and other structures. The implication is that more areas of the town are being made impermeable. While sediment source areas may be decreasing, the water gathering areas, for erosion, are increasing.

Sediment Hazard Perception: A questionnaire survey was carried out to elicit information from respondents as to how they perceived the 'sediment pollution' problem. Responses to the problems were grouped into five headings (Table 5)

The perception analysis revealed that the most active road users like taxi drivers, private car owners, and motorcyclists perceived sediment as hindrance to mobility. Those who perceived sediment as an aftermath of flooding are mainly those who lived near to sediment hazard area and had, therefore witnessed the flooding after rainfall. Those who perceived 'sediment pollution' as health hazard and environmental blight represent the well educated segment of the respondent. However those who could not specify represent the less educated or the illiterate members of the respondents. It is worthy of note that a large proportion of the interviewed see sediment redistribution as a norm. Regrettably too, this appears to be the position of the Government as revealed by top government functionaries interviewed.

POSSIBLE SOLUTIONS

The proper and adequate measures that should be adopted toward sediment control in Ekpoma may be itemized thus.

Table 4: Land use types in Eguare and Ujoelen Quarters (1963-1982)

Eguare Quarter	*1963 (%)*	*1973 (%)*	*1982 (%)*
Area covered by concrete/roof/roads (tarred/impermeable footpath/street)	50.33	65.68	68.48
Area between building (usually bare and impermeable)	13.84	4.47	2.00
Bore/grass/agriculture/tree covered land	35.83	29.85	9.70
Number of houses	60	97	204
Ujoelen Quarter	1963 (%)	1973 (%)	1982 (%)
Area covered by concrete/roof/roads (tarred/impermeable footpath/street)	33.85	52.3	64.92
Area between building (usually bare and impermeable)	2.64	4.61	3.10
Bore/grass/agriculture/tree covered land	1.40	63.46	35.57
Number of houses	35	66	150

Source: Aerial photographs and fieldwork, 2004.

Table 5: Sediment hazard perception in Ekpoma; the responses from 250 questionnaires

Principal listed cause for concern	*Number of respondents itemizing this concern*	*Percentage of total*
Hindrance to mobility	85	42.5
Flooding	62	31.0
Environmental blight	46	23.0
Health	30	15.0
None specified	27	13.5

Source: Statistical computation

1. It is suggested that planned collection and guidance of rainfall from existing house roofs to storm channels be encouraged. Should this be done, it is hoped that houses, particularly those in hill slopes will not become sources of water for erosion and sediment redistribution.
2. The need for proper use of vegetation for both temporary and permanent control of sediment is advocated. In this regard, all bare surfaces like private compound, road 'islands' and sidewalks need to be covered with grass or other protective materials. It is also suggested that legislation from government will certainly improve the environment.
3. Where high velocity flows cross the roads, (as in the case with road junctions) culverts with sediment intake holes cannot be neglected.
4. Drainage channels should be expanded to accommodate the augmented increase from runoff.
5. The attitude of indiscriminate dumping of refuse into drainage channels and sewers must be discouraged, and if possible, legislated against by the concerned local government authority.
6. In areas of perennial and persistence sediment problem, gutters should be constructed from sides into debris basins.
7. Personnel and equipment should be increased urgently. Besides, the equipment must also be functional and in good condition.

CONCLUSION

At the moment, Ekpoma is experiencing serious sediment problem particularly during the wet season when most of the road surfaces are covered with sediment. The rapidly changing nature of the land use pattern is increasing the storm runoff sediment source areas. The drainage channels have therefore become too small to accommodate the storm water. There is also no agreement between the town planning and natural erosion processes. Again, a lot (over 90%) of Ekpoma residents recognized the 'sediment pollution' problem. However, as with the Government, accepted the situation and see it as a situation that cannot be redress.

These situations notwithstanding, planting vegetation on bare surfaces, upgrading the present storm drains as well as construction new ones in areas where they are not in existence could reduce the sediment problem in Ekpoma. Sediment culverts should be used at T-junctions and the government should mobilize the people in getting rid of the sediment through self-help or do-it-yourself awareness campaigns. The Local Government Authority (LGA) should substantially increase both men and equipment used for cleaning the environment.

These measures, it is hoped, will go a long a way to improving the aesthetic quality of Ekpoma when strictly implemented.

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