European Environmental Sciences and Ecology Journal (EES)

2014 / June

European Scientific Institute (ESI)

Reviewed by the "European Environmental Sciences and Ecology Journal" editorial board 2014

June 2014 edition vol. 1, no. 1

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INTRA-URBAN PARKING CAPACITIES AND PARKING DEMANDS IN AKURE, ONDO-STATE

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Abstract

The dominant means of intra-urban mobility in Nigeria is the motor vehicle whose traffic situation has deteriorated to an alarming extent in recent years. The situation is worsened when parking facilities as a major element of urban transportation development is neglected in the face of increasing activities which generate enormous parking demand. The aim of the study therefore is to examine intra-urban circulation system and its parking demand against the background of transport infrastructure on ground in Akure metropolis. A reconnaissance survey was carried out to delimit the study area into ten activity areas. The ten purposively selected activity areas were chosen based on land use activities to represent the sampling frame. Car park users and respondents working within a 20 metre radius in each activity centre were randomly selected for interview with the use of a questionnaire. The data collected were subjected to student t-test analysis to show that there is no correlation between available parking space capacities and parking space demand in Akure. The result shows that the core area of the city which is basically commercial is extensively used and as such attracts heavy traffic without corresponding parking lots. The study recommends that both state and local governments should work together to identify vacant lands for car park development.

Keywords: Activity areas, vacant land, parking space, mobility, traffic situations

Introduction

One of the inescapable basic needs of modern societies is transport which many scholars have identified as the arteries and lifelines through which national economic systems function (Ogunbodede, 2010). This is

particularly true of modern urbanized societies where great distance separate various forms of land use systems be they residential, cultural or recreational (Temidayo, 2008). In fact, one of the major dilemmas of planner is how to relate and use transportation system in the efficient ways with regards to the social structure, the needs of the people and within the available resources.

Cities are locations having a high level of accumulation and concentration of economic activities and are complex spatial structures that are supported by transport systems. According to Ogundare (2013), the most important transport problems are often related to urban areas and take place when transport systems, for a variety of reasons, cannot satisfy the numerous requirements of urban mobility. Urban productivity is therefore highly dependent on the efficiency of its transport system to move labour, consumers, and freight between multiple origins and destination. Some problems are ancient, like congestion which plagued cities such as Rome, while others are new like urban freight distribution or environmental impacts (Rodrigue, 2011).

Vehicular parking had been one of the major problems affecting cities all over the world. While structures assume high scraper in nature thereby housing many vehicle owners, the space provided for such areas are usually inadequate. In automobile dependent cities all over the world, this can be very constraining as each economic activity has to provide an amount of parking space proportional to their level of activity. Parking has therefore become a land use that greatly inflates the demand for urban land.

The most striking feature of Cities therefore is the large concentration of business activities along certain arteries in and around the central business districts. The difficulty of having a place to park vehicles in the city now constitutes a major urban transport problem. The inadequacies of parking supply are due to poor urban planning and encroachment on existing parking spaces. On the demand side, there has been a tremendous increase in the number of vehicles and this has created a high demand for parking spaces. As parking supply falls, and parking demand rises, the degree of parking deficiency is increased. The consequence of this high parking deficiency are; total blockade of roads in some cases; narrowing of available road spaces; reduced vehicle speed, increased travel time; slow to almost impossible emergency and rescue operations.

It is against this background that this study examines the correlation between parking demands and parking provisions in Akure with a view to making planning recommendations for its adequacy if any.

Conceptual Framework

Spatial organization of a city defines interaction within it and the efficiency of this interaction is a function of the economy of the city and the

ease with which movement is undertaken (Tanimowo and Atolagba, 2006). Different approaches have been undertaken to explain interaction within a city in terms of its spatial organisation and land use activities. Johnson (1972) identified three of such approaches or theories.

The first of such theories was propounded by Ernest Burgess (1923), known as the Concentric Theory of land use location. It assumed that development of a city follows an outward growth from its central area in a series of concentric zones and that intra-city movements primarily influence the shape of such growth. The second was the Sector Theory of Hoyt and Davis (1939), which traced the historical growth of cities along travel routes in which different parts of sectors of the city take a star-like shape as defined by route ways from the centre to the suburbs. The third was the Harris and Ullman (1945) Multi-nuclei Model, which propounded that there were multiple centres in different parts of the city, each specializing in different types of land use.

However, what appear to be common to these models are the functions or activities in a city that are determined by its economy and the interaction of people with the activities through intra-urban movement. Specifically, what this means is that there can never be a city without movement among land uses within it and that according to Etim (2007), circulation pervades every aspect of urban life.

Land use and transportation studies in Nigeria have been restricted to big cities like Lagos, Ibadan, Port Harcourt, and Kaduna, while medium cities and rapidly developing state capitals have been grossly neglected (Ogunbodede *et al*, 2008). It is in line with the above stated that using Akure as a case study was justified. Akure as a medium sized urban centre and a rapidly developing state capital therefore needs attention before it starts to experience traffic problems. It is envisaged that the increasing urban population, locational arrangements of activities and land uses coupled with the increasing functions might result in more complex traffic problems in the years ahead, since the peak hour traffic problems have already started.

Hypothesis

In an attempt to determine need for parking space in the presence of available parking spaces in Akure, the null hypothesis below was tested as part of the funding of this research:

H_o: *There is no difference between the available parking space capacity and parking space demand in Akure.*

The Study Area

Akure the setting for the study is a traditional Nigeria city and like other traditional Yoruba towns in the country, existed long before the advent

of British Colonial rule. The city is located within Ondo State in the South-western part of Nigeria, (Fig. I). Akure lies approximately 7^0 15^1 North of the Equator and Longitude 5^0 12^1 East of the Greenwich Meridian. Akure is a medium-sized urban centre and became the provincial headquarter of Ondo Province in 1939. It also became the capital city of Ondo State and a Local Government headquarter in 1976. Consequently, there was heterogeneous massing of people and activities in the city (Ogunbodede, 1999).

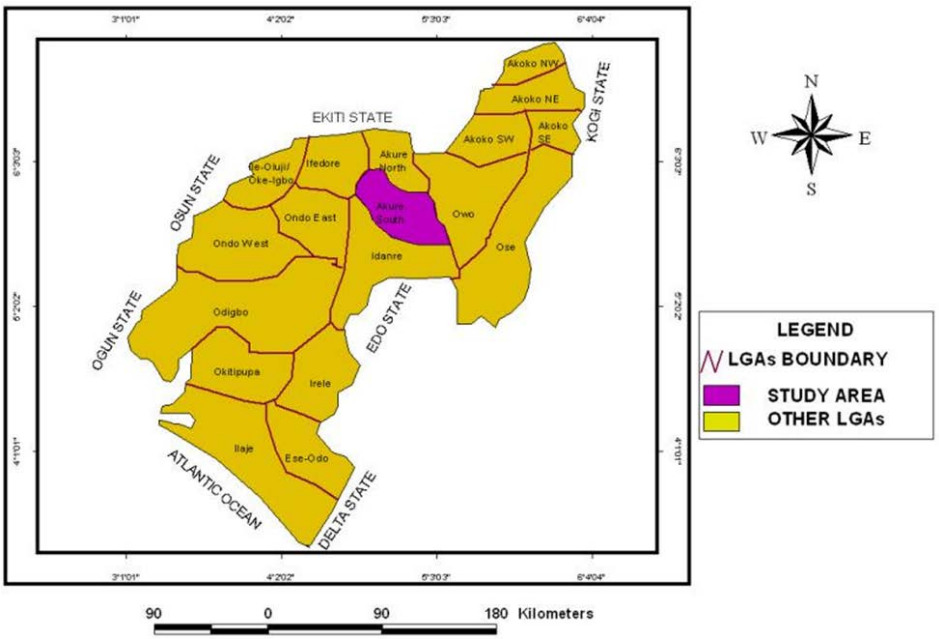

Fig. I: Ondo State Showing Study Area (inset: Nigeria showing Ondo State)
Source: Ondo State Ministry of Lands and Housing, Akure (2005)

The city's morphology has changed over time to assume its present status with its attendant transport problems, as experienced in similar medium sized urban centres in Nigeria. The increased relative political influence of Akure as a state capital since 1976 has greatly promoted its rapid growth and increased socio-economic activities. The population of the city grew from 38,852 in 1952 to 71,106 in 1963. Its population was estimated to be 112,850 in 1980 (DHV, 1985); and 157,947 in 1990 (Ondo State of Nigeria, 1990). The 1991 national population census put the population of Akure at 239,124 and its estimated population in 1996 was 269,207 (NPC, 1996). However, a sharp increase was recorded in 2006 census, which put Akure south population at 353,211 and Akure north population at 131,587 respectively (NPC, 2006).

The increase in population over time and space is evident in economic activities including daily trade in commodities carried out in a

network of traditional and modern markets, hotels and guest houses, dotting the landscape of both inner and outskirts of the city. These activities have subsequently increased the number of traffic and volume of travel in the city as people travel between their homes and places of work, religion, markets, hospitals, and recreational centres.

In addition, the city being strategically located in the heart of the State is linked by fairly good roads to all other local government areas which generate considerable daily road traffic flow in the central city. Space demand to park vehicles at places of destinations is therefore high with almost all the commercial and business centres located within the central city without designated parking areas. Consequently, vehicles are usually parked indiscriminately along the roads creating traffic obstruction and travel delay. Thus, parking problems have remained a major problem of the city.

Method of Study

The first step in the research methodology involved the identification of activity centres in the city. Thus, a reconnaissance survey was made in order to obtain first-hand information about the locations of parking spaces and various activity centres in the metropolis. The reconnaissance exercise guided the delimitation of the study area into ten activity areas. The ten purposively sampled activity areas were selected based on land use in the study area (see Table 1).

Table 1: Land use and Activity Areas in Akure

S/N	Land use	Activity Area
A.	**Administrative**	(i) Ondo State Secretariat (ii) Akure South Local Govt. Secretariat
B.	**Commercial**	(iii) First Bank (iv) Nepa Market (v) Oba's Market/Post Office (vi) Isikan Market
C.	**Educational**	(vii) Federal College of Agriculture (viii) Federal University of Technology
D.	**Health**	(ix) General/Specialist Hospital
E.	**Recreational**	(x) Owena Motels, Akure

Source: Field Survey, 2012

The data for the study were obtained from primary sources through administration of questionnaires. Information needed and which were collected through the questionnaire include: the nature or type of parking, duration of parking, the need for parking, type of vehicles involved, perception of car parking in the location, as well as the extent of adequacy of parking spaces in the activity centres. Fifty copies of the questionnaire were administered to both car park users and respondents found within a 20 metre

radius in each activity centre using random sampling technique. In all, a sample size of 500 copies of the questionnaires was used.

Moreover, through field survey and observation, vehicular traffic census to activity areas were carried out and measured against existing parking spaces in order to assess the level of parking convenience available per activity area. In addition, other relevant materials and data were sourced from published and unpublished official records, articles, Ministry of works and Transport and internet among others. Appropriate statistical techniques including frequency tables and percentage were used to explain the result of the study.

Presentation of Data

Respondents' characteristic and classification

Table 2 depicts the pattern of sex structure of the respondents as obtained from field investigation. Analysis of Table 2 shows that a high proportion of the respondents (82%) are males while the remaining 18% are females. The increase in the percentage of males over that of females can be attributed to the fact that, like elsewhere there are more male drivers than females.

Table 2: Sex of the Respondents

Sex	Frequency	Percentage (%)
Male	410	82.0
Female	90	18.0
Total	**500**	**100.0**

Source: Field Survey, 2012

The information provided in Table 3 shows that majority of the respondent (64%) who are between 25 – 50 years were of the active working age. About 26% 0f the respondents were below 25 years of age while only 10.4% claimed to be above 50 years. This observation shows that the bulk of the respondents are youths whose age fall below fifty years, and they are mixture of young private car owners and public transport drivers. Since these set of respondents are really involved in active driving within the city, they are in the best position to give information on intra-urban transport circulation in Akure metropolis with its attendant parking situations and problems.

Table 3: Age of Respondents.

Age (Years)	Number of Respondents	Percentage (%)
Below 25	128	25.6
Between 25 – 50	320	64.0
Above 50	52	10.4
Total	**500**	**100.0**

Source: Field Survey, 2012

Questions relating to educational qualifications of respondents were asked for. The information revealed that about 5% of respondent had no formal education while about 14% had primary school certificate. Respondents with secondary and post-secondary education constitute more than 80% of the total respondents. The few who had primary or no formal education are mostly commercial and or cab drivers who form part of those that stop at unauthorised places to pick and drop passengers.

Table 4: Educational Background

Educational Qualification	Frequency	Percentage (%)
No Formal Education	26	5.3
Primary Education	68	13.6
Secondary Education	131	26.2
Post-Secondary Educ.	275	55.0
Total	**500**	**100.0**

Source: Field Survey, 2012

Parking Capacity and Parking Demand

Intra-urban trips in Akure indicate the form of spatial interaction of various land uses, which provide a measure of the spatial organization of the city. The travel efficiency relates to the cost of movement in terms of time value, distance, and convenience. Convenience in this study relates specifically to parking. Trip generation and attracting capacity of land use in terms of the number of vehicles and parking demand is used as a gauge to assess the functional role of each zone in terms of space efficiency. Table 5 provides data on vehicular traffic count as a measure of parking demand per activity area and the actual parking capacity in existence.

Table 5: Parking Capacity and Parking Demand in Designated Activity Centres

S/N	Activity Centre	Parking Capacity/Car	Parking Demand/Car
1.	First Bank	48	120
2.	Ondo State Secretariat	150	430
3.	Akure South LGA Secretariat	20	60
4.	Nepa Market	30	85
5.	Oja Oba/Post Office	47	250
6.	Isikan Market	60	92
7.	Federal College of Agriculture	06	21
8.	Fed. University of Technology	10	44
9.	General Hospital	52	160
10.	Owena Motels	40	45
	Total	**463**	**1307**

Source: Field survey, 2012

The Table shows that parking demand in the designated activity areas of the city is indicative of high demand when compared with the existing parking spaces, and reflects the volume of vehicular traffic per hour to these activity areas. Only one of the activity areas, that is, Owena Motels have fairly adequate parking spaces. At Ondo State Secretariat and Oja Oba, parking conditions are very acute and existing demand outweighs the parking spaces. What this development implies is that vehicles in these areas are parked along the roads.

The nature of this relationship can be further expressed statistically using the t-test analysis for the hypothesis. Table 6 below shows the summary of analysis.

Table 6: The Summary of t-test Analysis

Variables	Degree of Freedom	Level of Significance	Calculated Value	Tabulated Value	Decision
Available parking capacity and parking demand in Akure	(n_a+n_b-2) = (10+10-2) = 20 – 2 = 18	0.05 or 5%	2.143	2.100	H_0 is rejected while H_1 is accepted

Table 6 shows that at 18 degree of freedom and at 0.05 or 5% significant level of confidence, the computed t-test value is 2.143 and this exceeded the tabulated (critical) value of 2.100. Since the calculated t-test value is greater than the tabulated value, the null hypothesis that there is no difference between the available parking space capacities and parking demand in Akure is rejected, and the alternate hypothesis accepted. Therefore, it can be confirmed that there is difference in the available parking capacity and parking demand in Akure. Thus, the result shows that there are no enough parking spaces in the activity centres, and this has led to parking in un-authorised places. The implication therefore is that more parking spaces should be provided at the activity centres to take care of space demand for parking.

Planning Implications and Conclusion

The study has empirically established parking in Akure as a major road circulation problem. Many businesses in the area are without their own parking places and the volume of their businesses seems to be adversely affected. However, field investigation shows that vacant lands abound along the major streets of the city and they offer substantial amount of buffer zone for parking spaces.

Planning for parking facilities in the city should start with identification and inventory of vacant lands for car park development. These vacant lands can be built on the basis of either private or public ownership,

and car owners can pay some fee to park their vehicles. The planning should also be comprehensive enough to include the provision of on-street parking to augment demand where the road carriage way is wide enough to accommodate one-way parallel parking. However, parking in adjacent and unauthorized spaces, which are perpendicular to street corridors should be prohibited to ensure effective patronage of the designated parking areas in the city.

All public buildings must make allowance for parking spaces before approvals are given to their building plans.

All sky scrapers in the city-centre must be encouraged to provide parking spaces in each floor.

Government must also use buffer zones in the city centre to provide parking spaces for people who daily visit the area for commercial and marketing purposes.

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SALINITY (NACL) TOLERANCE OF FOUR VEGETABLE CROPS DURING GERMINATION AND EARLY SEEDLING GROWTH

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Abstract

In order to study salinity stress on four vegetable crops including radish (*Raphanus sativus* L.), cabbage (*Brassica oleracea* capitata L.), mustard (*Brassica juncea*) and water spinach (*Ipomoea aquatica*), a laboratory experiment as completely randomized design was conducted with three replications in the Department of Soil Science, University of Chittagong, Bangladesh. To create salinity stress, sodium chloride (NaCl) at five levels of 0 (as control), 2, 4, 8 and 16 dS m^{-1} were used. In the present study, indices such as germination percentage, germination rate, reduction of germination percentage, seed viability index, seedling and root length, seedling and root fresh weight of four vegetable crops were measured. Statistical results revealed that the effect of salt levels on investigated parameters was significant ($P< 0.01$)). Means comparison for these parameters showed that the application of 8 and 16 dS m^{-1} salinity resulted in the loss of germination percentage, germination rate, seed viability index, seedling and root length, seedling and root fresh weight of four vegetable crops, as compared to control treatment (0 ds m^{-1} salinity). In total, it can be concluded that salinity stress significantly decreased germination and growth parameters of seedlings of four vegetable crops.

Keywords: Salinity, seed germination, seedling growth, vegetable crops

I. Introduction

Salinization of soil is one of the major factors limiting crop production particularly in arid and semi-arid regions of the world (Ahmed, 2009). Salt stress leads to suppression of plant growth and development at all

growth stages, however, depending upon plant species, certain stages such as germination, seedling or flowering stage could be the most critical stages for salts stress (Khoshsokan *et al*., 2012). Germination and seedling establishment are critical stages in the plant life cycle. In crop production, stand establishment determines plant density, uniformity and management options (Cheng and Bradford, 1999). Seed germination is first critical and the most sensitive stage in the life cycles of plants (Ahmed, 2009) and the seeds exposed to unfavorable environmental conditions like salts and drought stresses may have to compromise the seedlings establishment (Albuquerque and Carvalho, 2003).

Plant growth is ultimately reduced by salinity stress but plant species differ in their salinity tolerance (Munns and Termaat, 1986).The major inhibitory effect of salinity on plant growth and development has been attributed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization (Hakim *et al*., 2009). Jamil *et al*. (2006) stated that salinity caused a significant reduction in germination percentage, germination rate, and root and shoots length and weights of four vegetable species. Despite the importance of seed germination under salt stress (Ungar, 1995), the mechanism (s) of salt tolerance in seeds is relatively poorly understood, especially when compared with the amount of information currently available about salt tolerance physiology and biochemistry in vegetative plants (Hu *et al*., 2005; Garthwaite *et al*., 2005; Kanai *et al*., 2007). The aim of this study was to evaluate the effects of salinity level on final germination percentage, germination rate, reduction of germination percentage, seed viability index, seedling and root length, seedling and root fresh weight of four vegetables species (radish, cabbage, mustard and water spinach).

Ii.Materials and Method

This experimental study was carried out under laboratory conditions in the Department of Soil Science, University of Chittagong, Bangladesh in a completely randomized design with three replications. This study consists of experiment on seed inoculation with salinity as NaCl at concentrations of 0 (distilled water as control), 2, 4, 8 and 16 dS m^{-1} on germination and early growth of four vegetable crops. Seeds of radish (*Raphanus sativus* L.), cabbage (Brassica oleracea capitata L.), mustard (Brassica juncea) and water spinach (Ipomoea aquatica) differing in salt tolerance, were used in this investigation. The seeds were surface sterilized with 5% NaOCl (sodium hypo chloride) for 5 min to avoid fungal invasion, followed by washing with distilled water. For each plant species, 10 seeds for each of the five NaCl treatments were used. Seeds were allowed to germinate in laboratory condition on filter paper (Whatman No. 2) in sterilized 9 cm petri dishes

soaked in a solution of the respective salt concentration. The number of germinant seeds was counted every day up to 10 days and the seeds were considered germinated when the radical emerged.

Final germination percentage, germination rate and reduction of germination Percentage (Azizi et al. 2011) were calculated as follows:

Final germination percent = S/T×100

Germination rate = N1/D1+N2/D2+ ... +Ni/Di

Where S is the number of germinated seeds, T is the total number of seeds and Ni number of germinated seeds, per day (Di).

Reduction of germination Percentage = (1-The number of germinated seeds conditions salinity/the number of germinated seeds conditions control)×100

At the end of tenth day, 5 seedlings were randomly selected and seedling and root length with their fresh weight were measured.

Also, seed viability index was determined by the following equation (Seghatoleslami, 2010):

Seed viability index =Final germination percentage × average seedling length (mm) / 100

Analysis of variance of data was performed with Microsoft Excel and MINITAB (Minitab, 1996) program and means were compared using Tukey's Multiple Range Test (TMRT).

III. Result

The results revealed that the final germination percentage and rate, reduction of germination percentage, seed viability index, seedling and root length, seedling and root fresh weight of radish, cabbage, mustard and water spinach were strongly affected (P<0.05) by all salt treatments (**Table 1-4**).

Salts stress on final germination percentage and germination rate:

The results of seed germination showed that, germination percentage and rate reduced with increasing salt concentration. Strong reduction was observed mainly at the higher level of salt concentration compared to control. Lowest mean germination percentage was observed in case of mustard (61 %) while the highest mean value was measured in radish (83%) (**Table 1**). The germination rate of the four vegetables species under observation showed marked differences in the timing of initiation and completion of germination (**Table 1**). In all seeds species except radish highest germination rate is related to the control treatment and the lowest rate is in the salt concentration of 16 dS m^{-1}. Germination response of radish at 2 dS m^{-1} was not significantly different from control. At higher salinity level (16 dS m^{-1}) the lowest germination rate was observed in mustard and water spinach while highest was observed in radish.

Salts stress on reduction of germination percentage and seed viability index:

Average reduction of germination percentage in different seed species showed the greatest reduction in salt concentration with 16 dS m^{-1} (**Table 2**). However at 16 dS m^{-1} salinity this reduction was more prominent in radish (47%) and cabbage (47%) than mustard (42%) and water spinach (37%). Means comparison showed that the application of 8 and 16 dS m^{-1} salinity resulted in the loss of seed viability index of four seeds species as compared to control treatment (0 dS m^{-1} salinity) (**Table 2**). Seed viability index of radish at 2 dS m^{-1} was not significantly different from control.

Salts stress on seedling and root length:

The continuous increase in length of seedling and root was observed in frequent hours of germination in four vegetable species in control as well as salt treatments. The data on the average length (**Table 3**) of seedling and root revealed that radish, cabbage, mustard and water spinach showed a strong inhibition with the increasing level of salt solution particularly at high salt levels (8 and 16 dS m^{-1}). The great reduction of seedling growth and particularly in root growth occurred with NaCl treatments in cabbage, mustard and water spinach compared to control. No significant difference was observed in seedling and root length of radish at 2 dS m^{-1} then control. Decrease in length of seedling was more prominent in radish than cabbage, mustard and water spinach. Although mustard, cabbage and water spinach showed sign of great affects on root length; great inhibition was recorded in radish. In contrast, seedling and root length of water spinach was less affected (**Table 3**).

Salts stress on fresh weight of seedling and root:

Statistical analysis showed that there were highly significant differences among all the vegetable species for seedling and root fresh weight. The fresh weight of seedling and root of all four species was strongly affected by all salinity levels. Seedling and root fresh weight were significantly reduced at high salinity levels (8 and 16 dS m^{-1} NaCl), whereas fresh seedling weight was reduced more as compared to fresh root weight. This trend was more prominent in radish than cabbage, mustard and water spinach at all salt levels except 2 dS m^{-1} NaCl. Highest seedling and root fresh weight of radish were recorded at 2 dS m^{-1} and was significantly different from control. However mustard showed less reduction. On the other hand fresh root weight of cabbage was strongly inhibited by all salinity treatments as compared to radish, mustard and water spinach. But this decrease was less in mustard (**Table 4**).

IV. Discussion

Salinity slowed the germination rate and at low concentrations the only effect was on germination rate and not total percentage of seeds (Shannon and Grieve, 1999). Generally, the decreases in the germination and seedling growth, due to the increase in the environment's salt concentration, are caused by physicochemical effects or by osmotic-toxic salts which exist in saline solutions. In fact, increasing the osmotic pressure (more negative osmotic pressure) resulted from the increased environment's salinity, on one hand disrupts the seed hydration, and on the other hand, the high concentrations of cations and anions (especially Na^+ and Cl^-) in the environment impede the seed germination by imposing toxicity in seeds (Rajabi and Postini, 2005, Atak *et al*., 2006). The adverse effect of salinity on plants can be caused by the loss of osmotic potential of root medium, specific ion toxicity and the lack of nutritional ions (Nabizadeh, 2002). Also stated that salinity imposes other stresses such as ion toxicity on plants, as a result of ion entry in excess of appropriate concentrations and nutrient imbalances, as commonly seen in the displacement of potassium by sodium (Khoshsokan *et al*. 2012). The reduction in seedling and root development may be due to toxic effects of the NaCl used as well as unbalanced nutrient uptake by the seedlings. The ability of the root system to control entry of ions to the shoot is of crucial importance to plant survival in the presence of NaCl (Hajibagheri, 1989). In addition, high salinity may inhibit seedling and root elongation by slowing down the water uptake by the plant (Werner and Finkelstein 1995).

V. Conclussion

In the present study, salt stress adversely affected the final germination percentage, germination rate, reduction of germination percentage, seed viability index, seedling and root length, seedling and root fresh weight of the four vegetables species. It can be concluded that salinity stress significantly decreased all studied seed germination and growth parameters of four vegetable crops and this information should be taken into consideration when crops grown under saline condition.

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Table1: Effect of salt (NaCl) stress on the final germination percentage (%) and germination rate (per day) in four vegetable crops.

Variables	Salinity level (ds m^{-1})	Radish	Cabbage	Mustard	Water spinach
Final germination percentage (%)	0	100 a	100 a	86.67 a	80 a
	2	100 a	83.33 b	60.0 b	66.67 b
	4	86.67 b	66.67 c	56.67 b	63.33 b
	8	73.33 c	56.67 c	53.33 b	60.0 b
	16	53.33 d	53.33 c	50.0 b	50.0 c
	Mean	82.67	72.0	61.33	64.0
Germination rate (per day)	0	5.0 a	4.75 a	3.50 a	2.42 a
	2	5.0 a	3.75 b	2.25 b	1.83 b
	4	4.08 b	2.75 c	1.75 b	1.75 b
	8	3.08 c	2.08 cd	1.33 b	1.50 c
	16	2.33 d	1.50 d	1.25 b	1.25 d
	Mean	3.90	2.97	2.02	1.75

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$.

Table2. Effect of salt (NaCl) stress on the reduction of germination percentage (%) and seed viability index (mm) in four vegetable crops.

Variables	Salinity level (ds m^{-1})	Radish	Cabbage	Mustard	Water spinach
Reduction of germination percentage (%)	0	0 d	0 c	0 c	0 c
	2	0 d	16.67 b	30.80 b	16.67 b
	4	13.33 c	33.33 a	34.64 a	20.83 b
	8	26.67 b	43.33 a	38.49 a	25.0 b
	16	46.67 a	46.67 a	42.33 a	37.50 a
	Mean	17.33	28.0	29.25	20.0
Seed viability index (mm)	0	5.25 a	4.25 a	4.72 a	1.90 a
	2	5.76 a	2.97 b	2.26 b	1.16 b
	4	3.95 ab	2.15 c	1.92 b	0.79 c
	8	2.54 bc	1.23 d	1.64 bc	0.71 cd
	16	1.10 c	0.56 e	0.46 c	0.51 d
	Mean	3.72	2.23	2.20	1.02

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$.

Table 3. Effect of salt (NaCl) stress on the seedling and root length (mm) in four vegetable crops.

Variables	Salinity level (ds m^{-1})	Radish	Cabbage	Mustard	Water spinach
Seedling length (mm)	0	5.25 a	4.25 a	5.42 a	2.37a
	2	5.76 a	3.55 b	3.77 b	1.74 b
	4	4.60 a	3.23 b	3.38 bc	1.25 c
	8	3.47 ab	2.17 c	3.08 cd	1.18 c
	16	2.07 b	1.07 d	0.93 d	1.03 c
	Mean	4.23	2.85	3.32	1.52
Root length (mm)	0	6.43 ab	4.67 a	6.66 a	3.15 a
	2	7.0 a	2.92 b	5.63 b	2.60 b
	4	4.13 bc	2.63 b	4.05 c	2.13 c
	8	4.07 c	2.47 b	3.35 c	1.03 d
	16	1.37 d	1.87 b	3.15 c	0.63 e
	Mean	4.60	2.91	4.57	1.91

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$.

Table 4. Effect of salt (NaCl) stress on the fresh weight of seedling and root (mg) in four vegetable crops.

Variables	Salinity level (ds m^{-1})	Radish	Cabbage	Mustard	Water spinach
Fresh weight of seedling (mg)	0	0.46 b	0.31 a	0.21 a	0.58 a
	2	0.69 a	0.26 b	0.16 b	0.37 b
	4	0.37 bc	0.20 c	0.13 c	0.30 bc
	8	0.23 cd	0.17 cd	0.10 d	0.24 c
	16	0.10 d	0.15 d	0.07 e	0.19 c
	Mean	0.37	0.22	0.13	0.34
Fresh weight of root (mg)	0	0.07 b	0.19 a	0.12 a	0.18 a
	2	0.14 a	0.13	0.09 ab	0.12 b
	4	0.05 bc	0.10 c	0.08 b	0.09 bc
	8	0.04 cd	0.05 d	0.05 c	0.07 cd
	16	0.02 d	0.03 d	0.03 c	0.05 d
	Mean	0.06	0.10	0.08	0.10

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$.

EFFECT OF OIL PALM EMPTY FRUIT BUNCHES (OPEFB) AMENDMENTS IN CRUDE OIL POLLUTED SOIL ON GERMINATION AND GROWTH PERFORMANCE OF WHITE MANGROVE SPECIES (LAGUNCULARIAA RACEMOSA)

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Abstract

The study investigated the effect of oil palm empty fruit bunches (OPEFB) amendments of crude oil polluted soil on germination percentage and growth parameter of white mangrove (*Laguncularia racemosa*). Soil samples were polluted with 1000ml of crude oil and amended with various quantities of (OPEFB) 0g, 100g, 200g, 300g and 400g and the control (unpolluted soil + seed). Germination percentage was analyzed after 21 days after planting and growth parameters were recorded at the end of nine (9) months. Results revealed that
crude oil pollution significantly affected the soil physical, chemical properties and nutrient contents which directly affect the germination and growth performance of *Laguncularia racemosa*. Oil palm empty fruit bunches amendments were able to
ameliorate the effect of the crude oil pollution and enhance the germination and growth performance of the white mangrove (*Laguncularia racemosa*) species. The remediation effect depend on the quantity of oil palm empty fruit bunches applied and the highest growth parameters were recorded in 400g of oil palm empty fruit bunches amended with crude oil polluted soil. This study revealed that crude oil polluted soil may have adverse effect on germination and growth performance of white mangrove species

((*Laguncularia racemosa*), but this can be remedied by addition of organic nutrients especially oil palm empty fruit bunches which act as a bioremediation and also organic manure that enhance soil fertility. It was recommended that oil palm empty fruit bunches which are byproducts from palm oil processing in the mill and may cause environmental pollution problems and spread diseases in the environment can be used in the amendment of crude oil polluted soils in the coastal community of Niger Delta region of Nigeria.

Keyword: Oil Palm Empty Fruit Bunches, amendments, Crude Oil, *Laguncularia racemosa*.

Introduction

Crude oil pollution has been, and will continue to be a significant source of environmental degradation in the Niger Delta region of Nigeria. The exploration and exploitation of crude oil pose a serious environmental problem due to contaminations of the products in air, water and soil in the oil producing communities (Trindade *et al.,* 2005). Crude oil varies in appearances and composition from one kind to another (Akaniwor *et al.,* 2007). Since discovery of oil in Niger Delta region of Nigeria, the ecosystem in the region has suffered untold hardship due to oil spillage, pipeline vandalization and transportation of crude oil derivatives. Crude oil pollution has been reported to have deleterious effects on both flora and fauna, and mostly affect the germination and growth performance of plant in the region (Kyung-Hwu *et al* 2004). Oil spills affect plants growth by creating conditions which make essential nutrients like nitrogen, phosphorous and oxygen needed for plant unavailable to them (Ogbo *et al* 2009). Pollution by crude oil has been found to decrease the dry matter content, moisture content, crude protein and crude fibre of *Telfairia occientalis*. (Ogbuehi *et al* 2010). Oil pollution have been found to reduced plant germination percentage, growth parameters and yield of crops such as *Arachias hypogea L.* and *Zea mays L.* (Abdulhadi and Kawo, 2006). Environmental pollution from activities of oil exploration and exploitation in Niger Delta region of Nigeria due to indiscriminate disposal crude oil is inevitable. Pollution of soils with crude oil, significantly delayed the period of germination velocity, reduced percentage germination, plant height, leaf production and biomass of *V. unguiculata* (Adedokun and Ataga, 2007). Although the effects of crude oil pollution on plants have been evaluated by many studies (Siddiqui and Adams, 2002; Anon, 2003; Andrade *et al*., 2004; Adedokun and Ataga 2007; Shahid, 2007), there is the need to find out a remediation method to counter the effects of crude oil pollution on germination and growth performance of mangrove species grown in the coastal area of Niger Delta of Nigeria.

Mangrove species is used as fuel wood, construction and building materials, drugs, chemicals, feed and food for the coastal dwellers. However, oil contaminated soils are amendable to bioremediation because micro-organisms capable of degrading petroleum hydrocarbons are present in organic matter (Jone and Edington 2005). Oil palm empty fruit bunch (OPEFB) is one of the organic matter gotten as byproducts left during palm oil processing in the mill. This palm is grown mostly in the Niger Delta region of Nigeria. The residues from oil palm especially Empty Fruit Bunch (EFB) may cause environmental pollution problems and spread diseases in the environment. They also serve as breeding ground for pests and disease causing organisms on the environment. Studies have shown that oil palm empty fruit bunch (OPEFB) can be used as fertilizer to improve soil fertility (Udoetok, 2012). This study therefore evaluates the effect of oil palm empty fruit bunches OPEFB) in enhancing crude oil degradation in soil on the germination and growth performance of white mangrove species (*Laguncullariaa racemosa*) in the Niger Delta region of Nigeria.

Botany of White Mangrove *(Laguncularia racemosa)*

The White mangrove *(Laguncularia racemosa*) is from the family Combretaceae, a native to the coasts of western Africa from Senegal to Cameroon. White mangrove species exist as a tree or shrub with maximum heights of l5 m. The leaf shape is a broad, flat oval rounded at both ends. Leaf lengths approach 7cm. Two glands are found at the base of each leaf at the apex of the petiole. When growing in oxygen deprived sediment the White mangrove often develop peg roots which are similar to pneumatophores except they are shorter and stouter in appearance.

Importance of Mangrove in Coastal Ecosystem

It is obvious that mangroves play an important role in maintaining a healthy coastal ecosystem by exporting large quantities of detritus and supplying abundant food and feed to aquatic organisms, maintaining nutrient cycling, biogeochemical functions and energy flow along complex food chains and food webs. It also provides a habitat for a variety of animals especially waterfowl and birds, and acts as a nursery for juvenile species through provision of food and shelter from predation. The prop roots and pneumatophores of mangrove plants, and the shading effect under the leaf canopy allow the small animals escape or hide from their predators. In addition to ecological functions, mangrove ecosystems are important to the subsistence livelihoods of tropical coastal communities (Kaplowitz, 2001 and Rivera-Monroy, *et al.,* 1999). At present, millions of coastal dwellers throughout the region are dependent on mangroves for their livelihoods. Mangrove ecosystems can be directly exploited by extracting fish,

agricultural products, and wildlife, as well as a variety of other goods including wood for fuel, construction and building materials, drugs, chemicals, feed and food (Kovacs, 1999). Mangrove ecosystems and their ecological functions also provide an array of important indirect services for people such as prevention of storm damage, flood and water control, support of fisheries, pollution mitigation, recreation and transport.

Material and Methods

Nigerian light crude oil was collected from Exxon Mobile Unlimited in Eket Local Government Area of Akwa Ibom State, Nigeria. The oil palm empty fruit bunches (OPEFB) was collected from palm oil mill industry in Utu Abak, Abak Local Government Area, Akwa Ibom State, Nigeria. The oil palm empty fruit bunches was grinded into fine powder with Nulux mills machine (Model RPM SR 400-061, Bombay, India) to pass through a sieve of 2mm mesh size. The soil sample used for the study was collected from the Botanical garden, Akwa Ibom State University, Ikot Akpaden, Mkpat Enin Local Government Area, Akwa Ibom State, Nigeria. The soil was sieved with 2mm mesh size before use. A total of eighteen (18) plastic buckets perforated at the base for easy drainage were used. Each treatment consists of 5kg of soil thoroughly mixed with 1000ml of crude oil and amended with various quantities of oil palm empty fruit bunches (OPEFB) (0g, 100g, 200g, 300g, 400g) respectively. The mixture was allowed to stay for two weeks (14 days). This was to allow free mixture of crude oil polluted soil and oil palm empty fruit bunches to maintain a uniform component mixture before the seeds of *Laguncularia racemosa* were planted. The control experiment was (loamy soil (unpolluted) + seeds of *Laguncularia racemosa*). The experiments were left for nine months and were exposed to rain and sunlight throughout the period of the study.

For germination study, healthy seeds of *Laguncullariaa racemosa* were obtained from Eastern Obolo Local Government Area which is a coastal area in Akwa Ibom State. The seeds were sorted out and then sterilized with 0.01% mercuric chloride solution for 30 seconds; the seeds were thoroughly washed several times with distilled water and air dried. During this treatment floating seeds or those that had bubbles were discarded. A seed of *Laguncullariaa racemosa* was sown in each plastic bucket containing the polluted soil amended with various quantities of oil palm empty fruit bunches. The criterion for germination was taken as emergence of 2mm (0.2cm) at the time of observation (Singh and Singh, 1981). Germination percentage was observed from seven to 21 (7 – 21) days after planting (DAP) and the percentage was calculated using the formula according to the International Seed Testing Association (ISTA, 2009):

Germination Percentage (%) = $\frac{\text{Number of seeds germinated X 100}}{}$

Number of seeds tested

Growth Parameters Measurement

The growth parameters of *Laguncularia racemosa* include the plant height, root length, leaf length, leaf width, leaf area, total number of leaf moisture content and dry matter content. The plants from each treatment were carefully uprooted washed in running tap water to flush out the soil particles. The plant height, root length, leaf length and leaf width were measured in (cm) using a meter rule at the end of 6 months. The leaf area was obtained in duplicates by placing the leaf on a graph paper of one square centimeter ($1cm^2$). The squares enclosed by the margin were counted after the trace. The squares which were divided by the leaves area were counted if they are greater than or equal to 0.5 cm^2. Those that were less than $0.5cm^2$ were ignored (Hoyt and Bradfied, 1962).

The mean of the duplicate figures was taken as the leaf area. The leaf numbers were obtained by visual counting of the leaves. The percentage moisture content of the sampled species was determined as follows. The difference between the fresh and dry weight of the plant species, this was done by measuring fresh weights of the plant species using Mettler P. 165 weighing balance. The weighed plants were dries in a Gallenkamp oven at 800C until the weights were constant. All the parameters were obtained at the end of nine (9) months.

Results

The effects of oil palm empty bunches (OPEFB) amended with crude oil polluted soils on the germination percentage of white mangrove species (*Laguncullariaa racemosa)* is presented in Figure 1. The result shows an increase in germination percentage of *Laguncullariaa racemosa* with increase in the quantities of oil palm empty bunches (OPEFB) in crude oil polluted soils. Treatment of crude oil polluted soil amended with 400g of oil palm empty bunches (OPEFB) showed a significant increase in the ($p<0.05$) germination percentage. The 0g treatment (zero treatment) of oil palm empty bunches (OPEFB) in crude oil polluted soil had the least germination percentage. The lower value of percentage germination observed in 0g (zero treatment) of oil palm empty fruit bunches may be attributed to the effect of crude oil pollution in soil which affect the physical and chemical properties of the soil and inhibit the germination of *Laguncullariaa racemosa* seeds. It was observed that the control treatment (unpolluted soil + seed) gave the highest germination percentage (100%) of *Laguncullariaa racemosa* seeds. The percentage germination of *Laguncullariaa racemosa* seeds sown in crude oil polluted soil amended with various quantities of oil palm empty fruit bunches were found in the following increasing order Control treatment

100%> 400g 98% > 300g 72% > 200g 65% > 100g 48 > and 0g 20%. Figure 2 showed the percentage moisture content and percentage dry matter content of white mangrove species (*Laguncularia racemosa)* after nine months. The percentage moisture content and dry matter accumulation of the white mangrove species treated with 400g of poultry manure out yielded all others treatment and was significantly ($P<0.05$) higher than the 300g, 200g, and 100g treatment of oil palm empty bunches (OPEFB). However, there was no significant difference ($p >0.05$) between the control treatment and 400g treatment of oil palm empty fruit bunches.

Plant heights, root length, leaf length, leaf width, leaf areas and the number of leaves in the control and 400g treatment with oil palm empty bunches (OPEFB) record the highest values (Table.1). There was a direct proportionate increase in plant height , root length, moisture contents and leaf area with increase in the quantity oil palm empty bunches (OPEFB) but reverse proportionate decrease in the growth parameters of *Laguncularia racemosa* plant with decrease in the quantities of oil palm empty bunches (Table 1). It was observed that the quantities of oil palm empty bunches (OPEFB) had significant effect on the leaf area with the highest effect observed in the control and 400g treatment (25 cm^2 and 22cm^2) respectively. There was an increase in the number of leaves as the quantity of oil palm empty bunches (OPEFB) increased and a reduction in the number of leaves on the 0g and 100g treatment of oil palm empty bunches (12 and 34) respectively. However, the number of leaves observed in crude polluted amended with various quantities of oil palm empty fruit bunches were found in the following increasing order Control treatment 85 >400g 73 >300g 58 > 200g 30 > 100g 22 >0g 8. The results showed that oil palm empty fruit bunches which is a waste product and constitutes environmental nuisance can degrade crude oil pollution in soil and also add manure to the soil.

Discussion

Crude oil pollution on coastal region of Niger Delta of Nigeria affects the germination and growth performance of *Laguncularia racesmosa* in the area as indicated in the results. The effect of the crude oil spillage on the plant height, root length, leaf area, moisture content and dry matter observed in the study were similar to those reported on the effect of crude oil on *Manihot esculentus* (Ogbuehi *et al* 2010). Njoku *et al*. (2008) found similar findings on the effect of crude oil on the growth of accessions of *Glycine max* and *Lycopersicon esculentum*. Etukudo (2004) also showed that treatment of soils with crude oil, automotive gasoline oil and spent engine oil significantly affected the time of germination, plant height, leaf production and biomass of *Abelmoschus esculentus*.. The decrease in germination of *Laguncularia racesmosa* seeds in 0g treatment of soil with crude oil

indicates that crude oil affect the availability of water, oxygen and temperature in the soil which are important factors responsible for seeds germination. The effect of crude oil polluted soil on leaf indicates that its interrupts with the photosynthesis process, thereby reduce the leaf area. According to Kathirvelan and Kalaiselvan (2007) the leaf surface area determines in large part the amount of carbon gained through photosynthesis and the amount of water lost through transpiration and ultimately the crop yield. Therefore the reduction of the leaf area as observed in 0g treatment of (OPEFB) in crude oil polluted soil implies that there would be low photosynthetic efficiency of the plant as much of the solar energy emitted by sun would not be absorbed by plant for photosynthesis. This can lead to poor growth of the plant with subsequent poor timber formation and low yield. According to Walker *et al*. (2001), availability of nitrogen in the soil directly affects the relative growth rate of plants. (Agbogidi *et al*., 2007) reported that petroleum products are known to reduce nitrogen availability in the soil. This could be the cause of adverse effect on growth parameters of Laguncularia racemosa observed in 0g treatment of (OPEFB) in crude oil polluted soil. According to Wyszkowski and Zoilkowska (2008), proper growth of crops is dependent on the content of nutrients availability in the soil. The inhibition of the growth of the white mangrove species (*Laguncularia racesmosa)* observed in the 0g treatment of oil palm empty fruit bunches may be due to the fact that crude oil affects the physical and chemical properties of the soil and also affect its nutrient contents. The adverse effects could be due to disruption of the absorption and uptake of nutrients by crude oil in the polluted soil, increase the soil pH and increasing acidity content of the polluted soil (Njoku *et al*., 2008). From the results, it can be concluded that oil palm empty fruit bunches can degrade crude oil polluted soil and it is effective bioremediation materials for crude oil pollution and at the same time restored the fertility of the soil, since it contain nitrogen, phosphorus, potassium and calcium which are essential to plant growth and development. Hence increase in the quantity of (OPEFB) in oil polluted soil will lead to increase in germination percentage of *Laguncularia racemosa*, increase in growth parameters and dry matter contents, thus, enhance timber productivity and yield of white mangrove species (*Laguncularia racemosa*).

Figure 1. Effect of Oil palm Empty Fruit bunches amended with crude oil polluted soil on Germination Percentage of *Laguncularia racemosa*

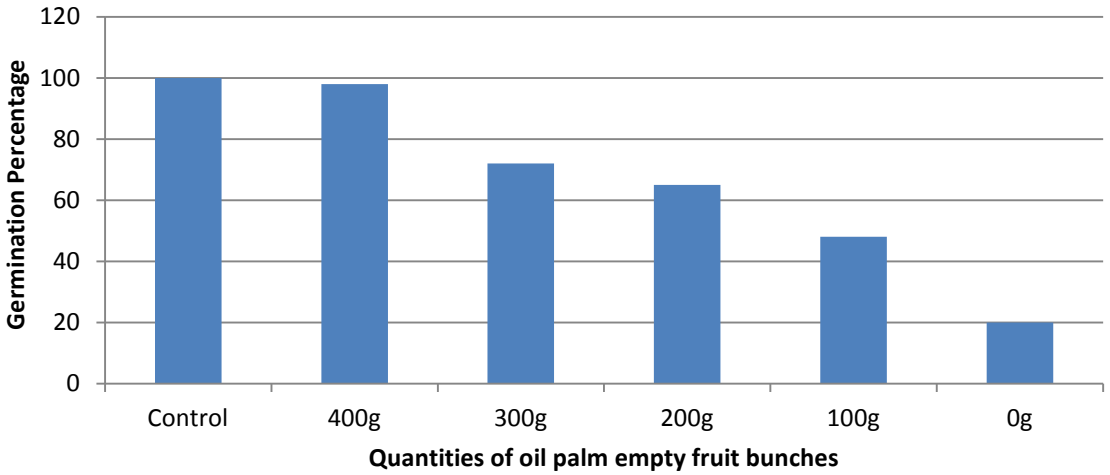

Figure 2. Percentage Moisture and Dry matter contents of *Laguncularia racemosa* after 9 months

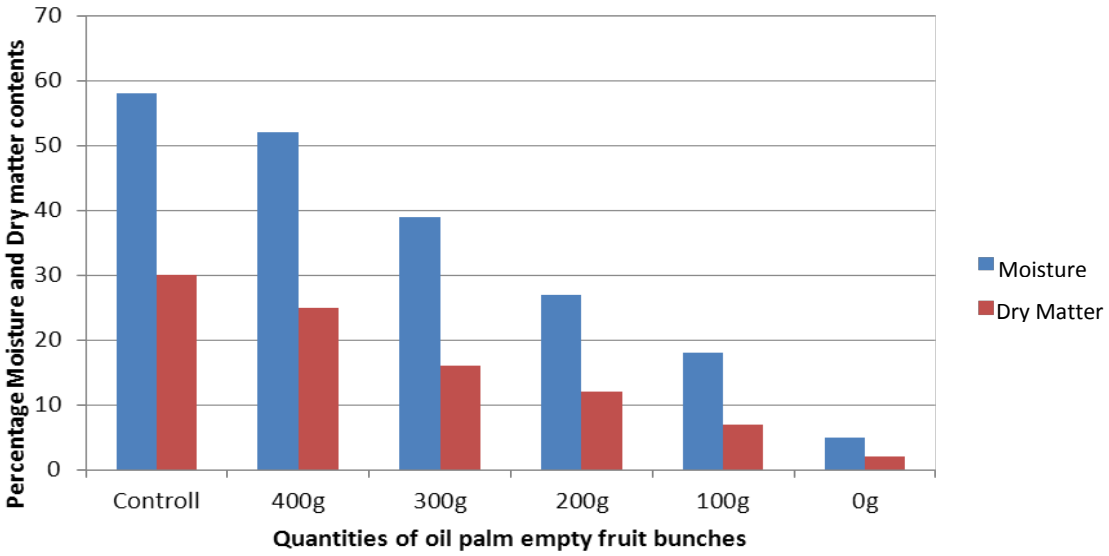

Table 1. Effect of oil palm empty fruit bunches amended with crude oil polluted soil on growth parameters of White mangrove (*Laguncularia racemosa)*

Growth Parameters	0g	100g	200g	300g	400g	Control
Plant height (cm)	15.14±0.04	98.15±1.34	153.02±0.29	178.14±0.10	278.25±0.19	295.15±0.05
Root length (cm)	6.94±1.25	51.10±3.05	75.19±0.72	84.19±3.25	128.39±0.01	136.01±0.40
Leaf length (cm)	2.10±0.05	6.13±0.55	8.14±1.25	9.42±1.00	13.05±0.10	14.02±1.05
Leaf width (cm)	073±0.15	2.78±1.22	3.15±1.05	4.19±1.15	7.12±1.00	8.03±1.20
Leaf area (cm^2)	1.18	12.78	19.23	29.60	69.42	84.05
Number of leaves	8	22	30	58	73	85

Data were processes and expressed as mean ± SD of three replicates

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THEORETICAL FRAMEWORK AND INITIATION OF SCIENTIFIC PROJECT "LIFE. MOTION OF ENERGY- ELEMENT INFORMATIONAL UNITY OF THE MATTER"

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Abstract

To provide a scientific answer to the questions "How did life originate?" and "How does life affect the Earth and the Earth affect life?" a concept of the function of energy-element-informational state of physical and biological systems *f* (E, C, I) has been developed. The regularities have been established and simulation of Life as a natural phenomenon, which is organized by moving in space and time energy-element-informational trinity of the Universe, has been run.

Keywords: Life, motion, energy, element, information, system model

Introduction

The U.S. National Research Council has formulated 10 key questions to which geologists and planetary scientists seek answers in the early 21st century. Among others, there are questions * How did life originate? * How does life affect the Earth and the Earth affect life?

Life is one of the forms of existence of the matter that occurs naturally under certain circumstances in the course of its development.

Modern science looks at material systems as matters, energy fields, noting that reflection is the universal property of the matter. The role of reflection (information processes) is of special importance for biosystems that actively perceive information from the external environment, transform it, use it for its development, accumulate, store and communicate it to the external environment.

Motion is an essential attribute of the matter. When moving a material system changes its *state* which is manifested in the change of *properties* of the system.

To be able to describe changes of the system state (with a complex change in its substance, energy and information) a scientific study of some concept, feature, function of unity of elements, energy and information is required.

Objective:

- To develop the concept of the function of energy-element-informational state of systems;
- To develop an overall picture (model) of the organization of life of the Universe, from nanosystems to the mega-level systems;
- To develop a plan for further multidisciplinary system research within the project "Life".

Results and Discussion

1. Function of Energy-Element-Informational State of Systems

The common (for physical and biological objects) components which together define the structure and properties of systems are:

- A qualitative and quantitative set of elements (C);
- A qualitative and quantitative set of energies (E);
- A qualitative and quantitative set of information (I);
- Configuration of the energy-element-informational path (S);
- The rate of change of the energy-element-informational state (v)

Physical and biological objects are considered (Bobukh, 2001; Bobukh, 2002; Bobukh, 2012a) as systems of qualitative and quantitative sets of energies $e_1, e_2,\ldots e_n$ = E, elements $c_1, c_2,\ldots c_n$ = C and information $i_1, i_2,\ldots i_n$ = I. Function f (E,C,I) is the characteristic of the energy-element-informational state of the system.

Figure 1 shows the schematic arrangement of hydrogen H, p-, s-, d-, f- elements depending on the values of the energy-element-informational function f (E,C,I) of each individual atom of the element as well as properties of systems formed from the atoms of H, p-, s-, d-, f- elements.

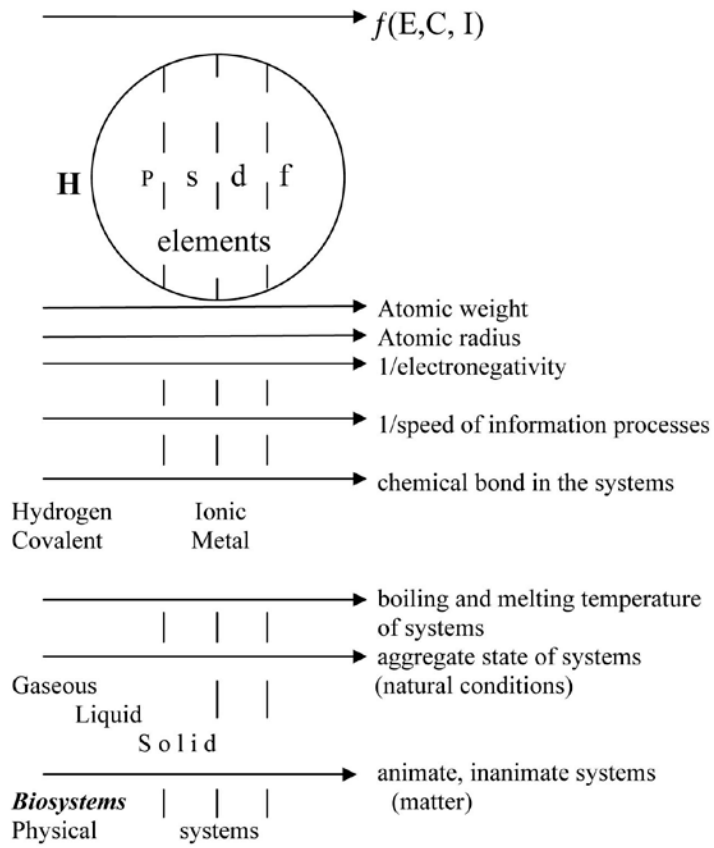


Fig. 1. Energy-element-informational function *f* (E,C,I) and properties of systems of H, p-, s-, d-, f- elements

Analysis of the established bonds makes it possible to designate elements that form systems with the lowest values *f* (E,C,I): element H as well as p- elements of the 2, 3 periods, IV-VI groups (H, C, O, N, P, S, Si – biogenic elements).

Biogenic elements have relatively low values of the atomic mass and atomic radius and high values of electronegativity and *the rate of information processes*. In the formation of molecules (CH_4, NH_3, H_2O) a covalent chemical bond is realized by the valence electrons, the atoms tend to sp^3-hybridization (H atom gives its single $1s^1$ electron; C, O, N, P, S - *p* electrons). Due to the intramolecular bond of H with C, O, N, P, S formation of DNA helical structure is possible (Fig. 2).

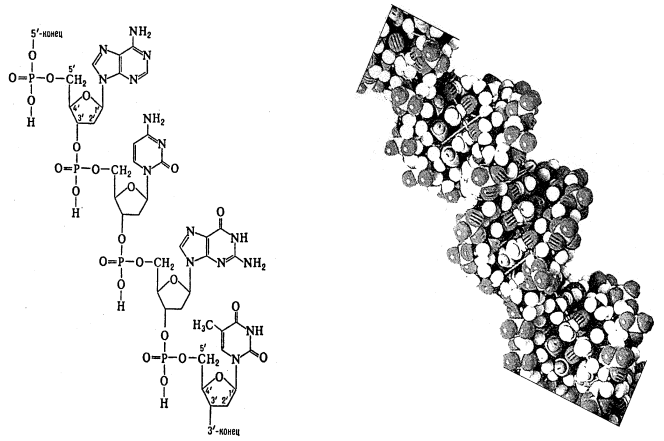


Fig.2. Structural formula and volumetric model of DNA

Usually by the properties of a chemical element are meant, firstly, the properties of its free atoms and, secondly, the properties of its elementary substance. Most of these properties have a clear periodic dependence on atomic numbers of chemical elements (a relevant number of protons in the atomic nucleus). Among these properties the most *studied*, significant, being of particular importance in explaining or predicting chemical behavior of elements and compounds formed by them are the following: *C* (atomic mass, atomic and ionic radii); *E* (ionization energy of the atoms, electron affinity energy, electronegativity, atomization energy of elementary substances, oxidation level, oxidation potentials of elementary substances).

As for the establishment of periodic dependence of change of the information properties (I – perception, transformation, accumulation, storing and communication) of atoms and systems they formed, these researches are just only beginning.

A group of physicists from the Max Planck Institute in Germany managed to "record" information about the quantum state of a photon to a single outer-shell electron (the outer shell configuration is 5 s^1) of a rubidium atom. The scientists have generated a photon and directed it at a rubidium atom. After the photon interacted with the electron, the researchers studied the behavior of the latter and came to the conclusion that the quantum state of the photon that "had hit" it could be quite accurately judged by the nature of motion of such electron round the atomic orbit. That is, the information has been recorded to the electron and, most importantly, the scientists succeeded in reading it.

It is probable that similar processes of “recording” – “reading” at the atomic level take place in nature, in the natural environment. For example, interaction of a photon (light – in a narrow sense) and $1s^1$ electron of a hydrogen atom causes a change in the informational state of the latter

("recording"). The hydrogen atom with a changed informational state, being an active participant of the construction of H_2O, DNA molecules, will change the informational state of the "reading" atoms C, O, N, P, S and the whole molecule of H_2O, DNA.

Thus, with maintained energy (E), element (C) characteristics, H_2O^I, $ДНК^I$ molecules will have an altered information characteristic (I) and so an altered energy-element-informational state of the system as a whole.

2. Motion. Change of Function of Energy-Element-Informational State of Systems

The rate of the system transition from one energy-element-informational state to another is:

$$v = \frac{\Delta f(E,C,I)}{\tau} \quad (1).$$

This equation (1) is a mathematical expression of the essence of matter which is the motion of the energy-element-informational unity.

Using the characteristic of change of Δf (E,C,I) and the equation (1) we can describe the rate of change of state of systems of various space levels, such as nano (Δf $(E,C,I)_{atom\ H}$, C – a hydrogen atom $1{,}67 \cdot 10^{-24}$ g; DNA), micro (cell), macro (organism), and mega (Δf $(E,C,I)_{Universe}$, C – the Earth $5976 \cdot 10^{21}$ kg, the Sun $2 \cdot 10^{30}$ kg , the Galaxy ~10^{11} of the Sun's masses)**.**

The way (S) of natural change of the energy-element-informational state of a system located anywhere on the surface of the Earth has a complicated cyclical pattern (Fig. 3) due to the mechanical motion of the Earth around the center of the Galaxy (1), the Sun (2) and its own axis (3). The state of the Earth – the Sun – the Galaxy physical system changes continuously and quite rapidly.

The Galaxy as a whole is moving relative to the background radiation at a speed of 620 km/s. The linear speed of movement of the Solar System around the center of the Galaxy is 220 km/s. The linear speed of movement of the Earth around the Sun is 29.765 km/s. The linear speed of the Earth's rotation at the equator is 0.465 km/s.

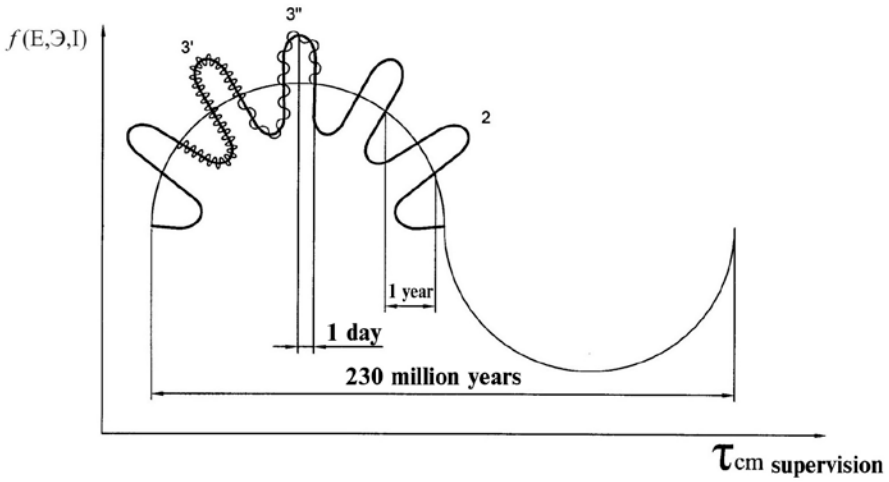
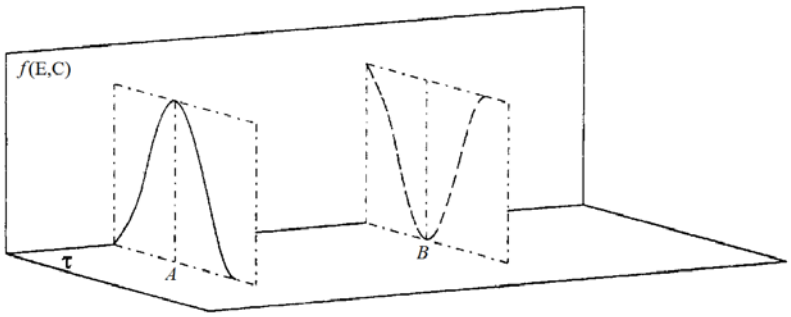


Fig.3. The equilibrium trajectory of change of the energy-element-informational state of any point on the Earth's surface the form of which is determined by the trajectory of the mechanical motion of the Earth around the center of the Galaxy (1) the Sun (2) and its own axis (3).

The change of state of the Earth – the Sun – the Galaxy physical system on the "spiral on a spiral, on a spiral" complex trajectory sets the same "mirror" trajectory (Fig. 4) of change of the energy-element-informational state of the system of biogenic elements H, C, O, N, P, S, generates a DNA helix, a cell, an organism.



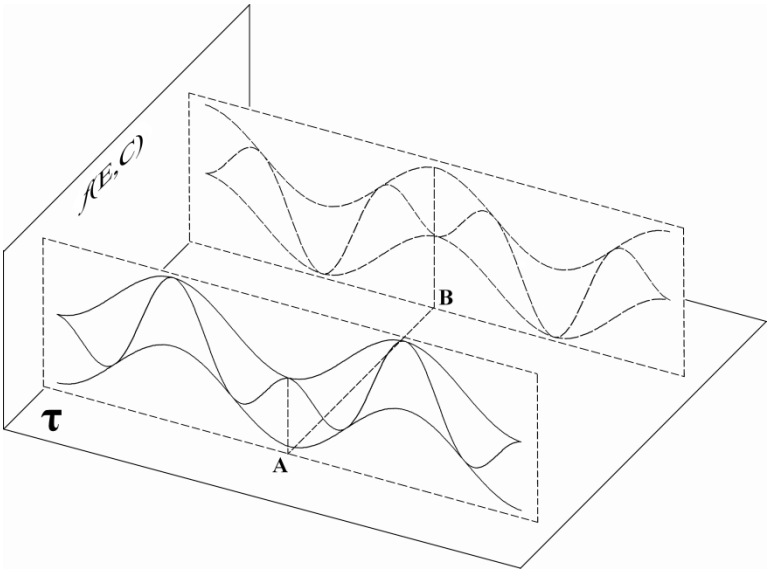


Fig.4. Diagram of dependence of change of the energy-element-informational function *f*(E,C,I) of biosystem (B) on the change of energy-element-informational function of the Universe (A). Diagram of Le Chatelier-Braun Principle

Due to the low values of the energy-element-informational inertia, the systems based on biogenic elements (perceived as biosystems) are able to change their states $\Delta f(E,C,I)_{biosystem}$ with speeds coherent with the natural rate of change in the characteristics of the environment $\Delta f(E,C,I)_{Universe.}$

The energy-element-informational *motion of the Universe "creates" a man* like all other biological systems (Fig. 5).

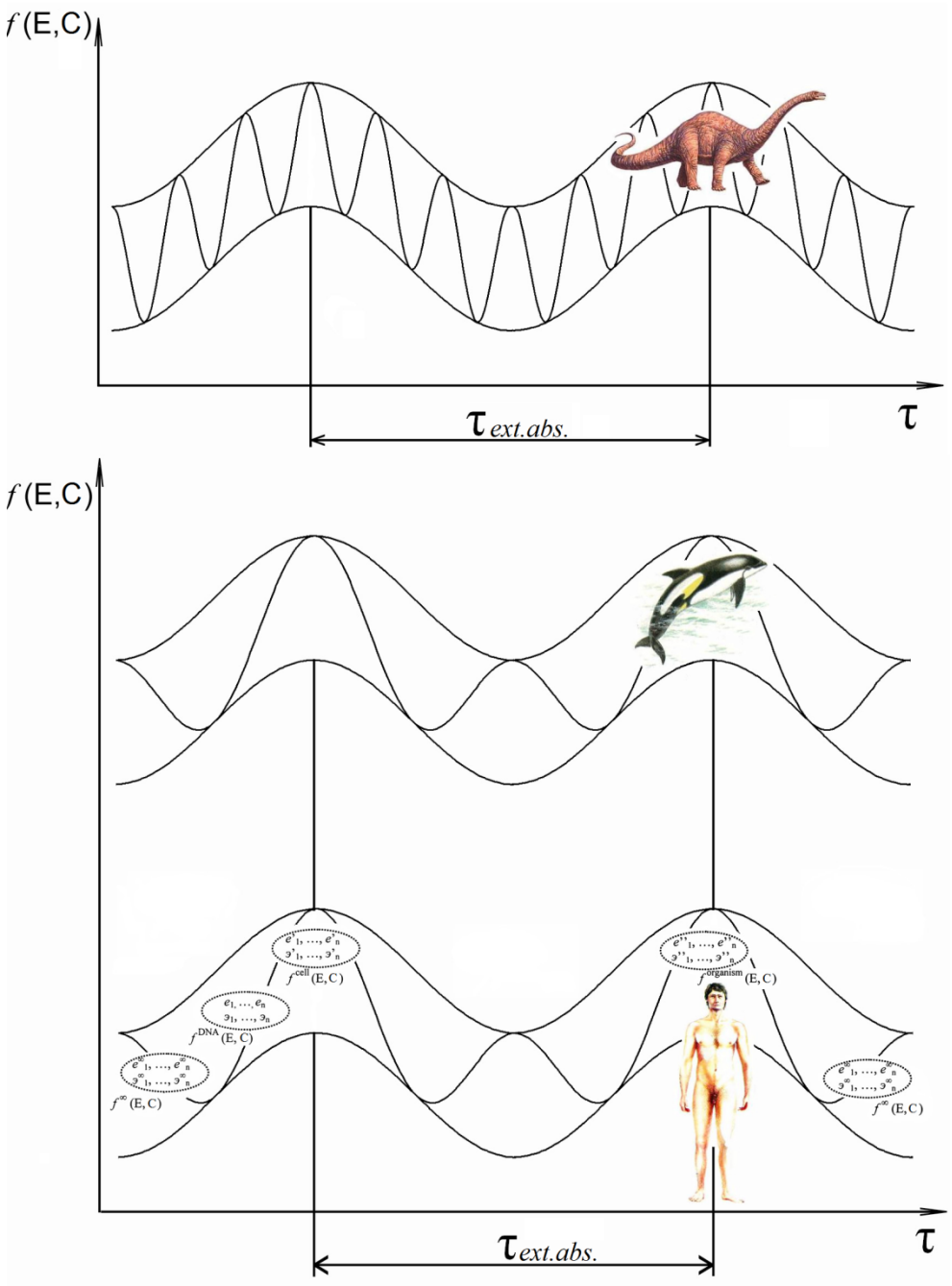


Fig.5. Organization and development of biological systems (DNA → cell → organism) taking place due to changing of the function of energy-element-informational state $\Delta f(E,C,I)$ of the environment; $\tau_{outside\ observer}$ is the length of time reviewed by an outside observer

A billion years ago a day lasted just 15 hours. But only blue-green algae or cyanobacteria, inhabiting the Earth at that time, could “see” it. Approximately 530 million years ago the Earth rotated so fast that a day lasted 21 hours. Its current rotation period is 24 hours. The rate of rotation of our planet around its own axis is slowing down.

We might say that the “Dinosaur” biosystem is organized by the Earth – the Sun – the Galaxy physical system at relatively high rotation rates of the Earth around its own axis. Organization of the “Man” biosystem is possible only at lower rotation rates of the Earth.

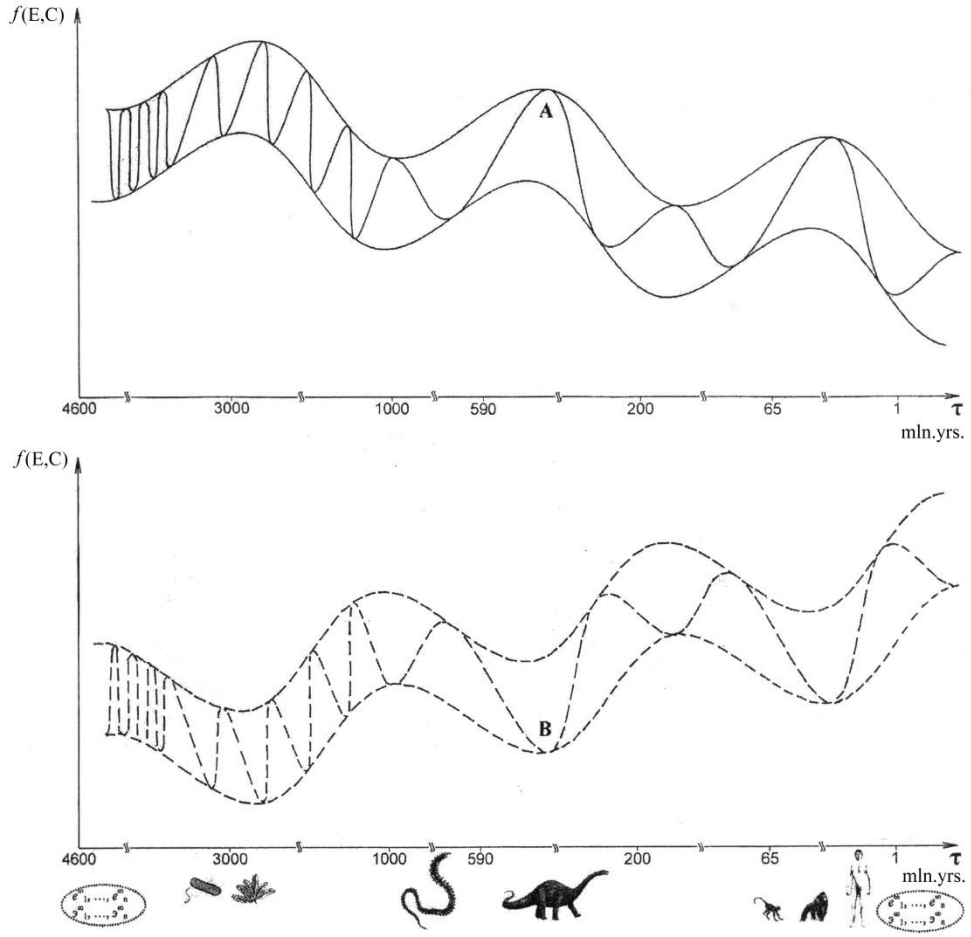


Fig. 6. Changing of the function of energy-element-informational state $\Delta f(E,C,I)$ of the Earth (A) and biosystems (B)

A “dramatic failure” (for example, sudden change of the speed of the Earth’s rotation at its collision with a large space body) in the natural mechanical motion of the Earth – the Sun – the Galaxy physical system on

any part of the "spiral on a spiral, on a spiral" trajectory can cause a disruption of coherence of oscillations of the energy-element-informational functions of biosystem and the Universe and result in the death of all or some of the biological systems existing at the moment of collision and organization of new biosystems meeting new requirements of coherence (Fig. 6).

3. Model of Life (Energy-Element-Informational)

In the practice of materials science to describe the state of an isolated physical system the scientists use the diagrams (Fig. 7) of element, energy – properties that are discrete in time. In this case it is possible to consider the state-property relationship both in each given point in time and throughout the a-в-d path.

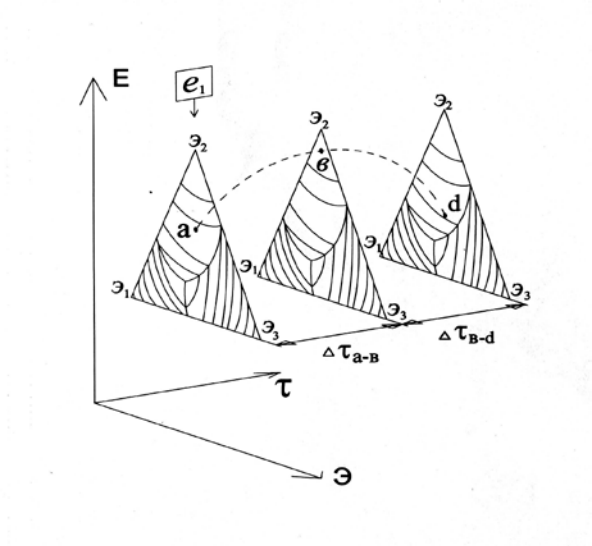


Fig.7. Diagrams of change of the energy-element state of a physical system, coordinates E-C-τ

When plotting diagrams of biosystems, the information content should be taken into consideration (Bobukh, 2009). A diagram shown in Fig. 8 plotted in E-C-I coordinates for biogenic elements H,C,O,N,P can serve as a tool for study of the energy-element-informational properties of prior-to-DNA, DNA structures, principles of cell, organism formation.

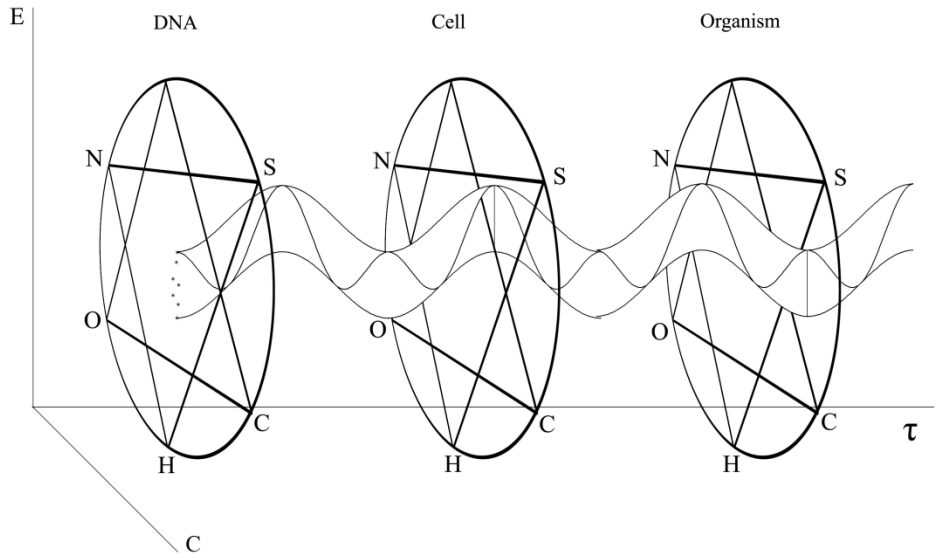


Fig.8. Diagrams of change of the energy-element-informational state of a biological system, coordinates E-C-I(τ)

Processes of organization and functioning of the energy-element-informational unity as a living system (biosystem) are the continuous time processes.

Such processes of continuous transition of an open biological system from one energy-element-informational state into another may be described (Bobukh, 2012b) with the help of a kinetic diagram (Fig. 9).

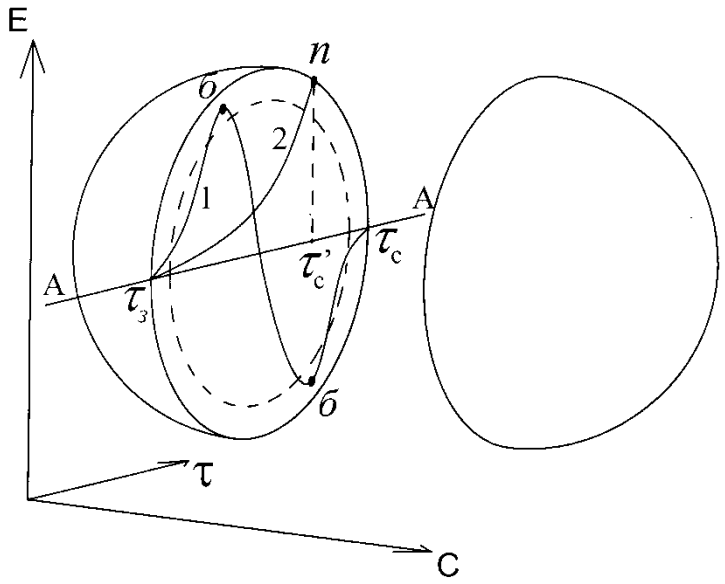


Fig. 9. Model of life of a biological system in the energy-element-informational space; A-A is a line of the energy-element-informational equilibrium; τ is a lifetime of the biosystem from birth (з) to death (с)

The model of life (Fig. 9) is part of the energy-element-informational space within which the natural processes of fluctuation of *f*(E,C, I) relative to the A-A equilibrium line take place. The graph above shows the passage of the f (E, C, I) value through a maximum over $t_3 \div t_c$ period of time from birth (coming into existence) to death.

Technical definition: Life is motion $v = \frac{\Delta f(E,C,I)}{\tau}$, a change of the energy-element-informational function f $(E,C,I)_{\text{of biosystem}}$ in the form of oscillations relative to an equilibrium state; a value of the amplitude of oscillations changes and, throughout the lifetime of the biosystem, passes through a maximum; the biosystem equilibrium state changes in accordance with changes in the equilibrium trajectory of the Earth as it moves in the energy-element-informational space of the Universe following the "spiral on a spiral, on a spiral" path …».

The surface on which the point of diversion of *f*(E,C,I) from the equilibrium state limits (rotation figures of Fig.10: ellipsoid, sphere, egg) the energy-element-informational (*en-el-info*) space in which the Universe organizes life.

Values of time $\tau_з \div \tau_c$ and volume $V_{f\ (E,C,I)}$ of existence of a biosystem can serve as a technical quantitative and qualitative characteristic of its life.

$f(E,C,I)$

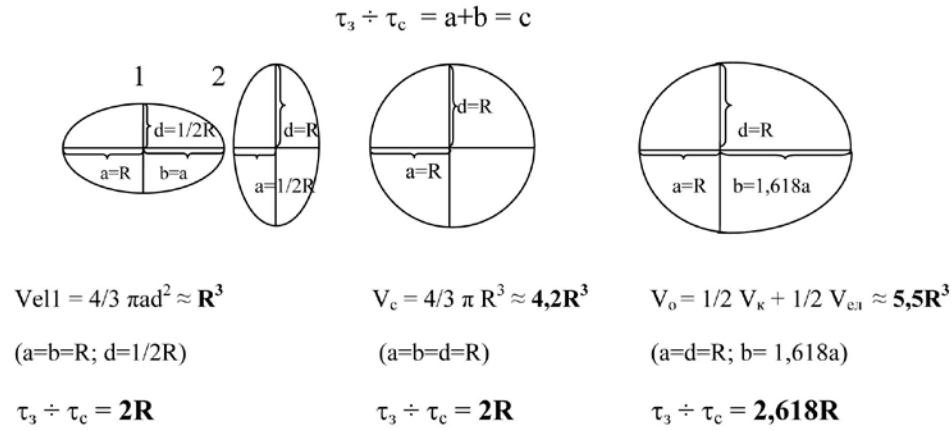


Fig. 10. Models of life (ellipse, sphere, egg) and values of quantitative and qualitative characteristic of life (time $\tau_з \div \tau_c$, volume $V_{f\ (E,C,I)}$)

Figures in the form of ellipses 1 and 2 have equal volumes $V_{ел1} = V_{ел2} = R^3$, wherein $(\tau_з \div \tau_c)_1 = 2R$; $(\tau_з \div \tau_c)_2 = R$. The values of volume and time are as follows: within the sphere $V_ш = 4{,}2\ R^3$; $\tau_з \div \tau_c = 2\ R$; within the egg $V_я = 5{,}5\ R^3$; $\tau_з \div \tau_c = 2{,}618R$.

Comparative analysis of time and volume of change of *f*(E,C,I) in the en-el-info space shows that it is the egg that has an optimal ratio and the largest values of the quantitative and qualitative characteristic of life ($\tau_з \div \tau_c$, $V_{f\ (E,C,I)}$).

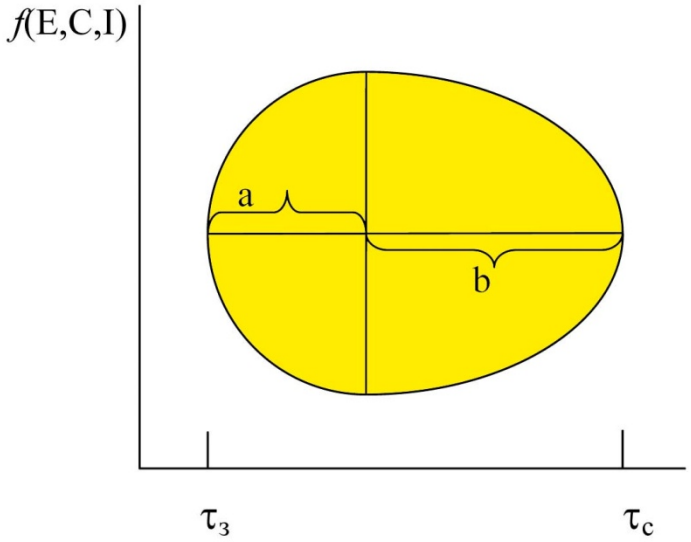


Fig.11. The “Golden Egg” of Life

The golden ratio has been recognized a universal law of living systems. Therefore the laws of the golden proportion were used to make mathematical calculations needed to produce a figure of an egg and its geometrical representation. The golden ratio is a proportional division of a line into unequal parts wherein the smaller segment refers to the bigger one as the bigger one to all a : b = b : c. The segments of the golden proportion are expressed as an infinite irrational fraction 0,618… if “c” is taken as 1, a = 0,382; (c : b = b : a = 0,382; b = 1,618a). Numbers 0,618 and 0,382 are the coefficients of the Fibonacci sequence.

Fig. 12 shows en-el-info models of life of biosystems 1 and 2. Both systems were born (came into existence) at the same time $\tau_{з1} = \tau_{з2}$. The lifetime of system 2 is longer than the lifetime of system 1; $\tau_{з2} \div \tau_{c2} > \tau_{з1} \div \tau_{c1}$. The volume of “development” of the en-el-info space by system 2 is bigger than that of by system 1; $V_{f\ (E,Э,I)2} > V_{f\ (E,C,I)1}$.

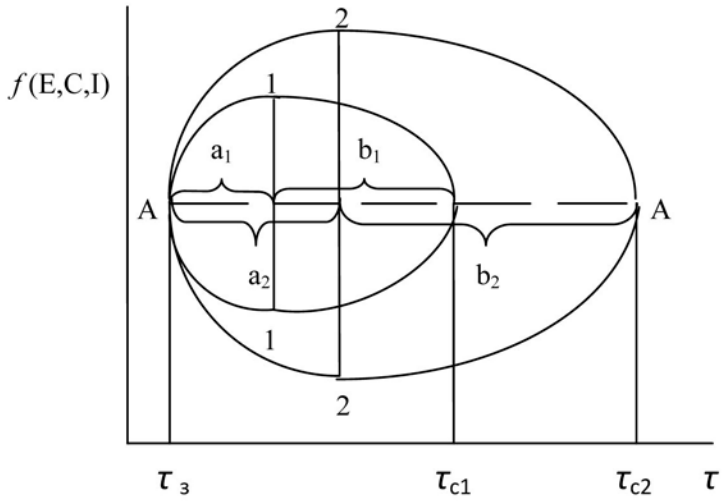


Fig. 12. Energy-element-informational model (egg) of life of biosystems 1and 2;
$\tau_з$ – time of birth (coming into existence), τ_c – time of death

Comparative graphical analysis of models 1 and 2 shows that the more vigorously the value of *f* (E,C,I) increases in the initial period of organization and functioning of the biosystem (from the moment of its birth $\tau_з$ to achieving maximum values of $f\,(E,C,I)_{1\text{-}1}$, $f\,(E,C,I)_{2\text{-}2}$) the larger the value of segment a ($a_2 > a_1$) will be and, as a natural result of the golden ratio principle, the value of length c ($c_2 > c_1$) and volume of life increases.

Man, as a biosystem endowed with brain, being aware of the regularities of natural en-el-info processes, has the ability to artificially influence the amount and quality of his life by purposefully changing the value of *f* (E,C,I).

The following calculations

1) a = 22,9 b = 37,1 c = 60;

2) a = 38,2 b = 61,8 c = 100,

made using an egg as a model of life show that if the maximum of increase in the value of *f* (E,C,I) is reached at the age of 22.9, then the total length of life is 60 years; if the maximum of increase in the value of *f* (E,C,I) is reached at the age of 38.2, then the total length of life will probably reach 100 years.

The total length of time of living of a person who purposefully, actively increases the value of his/her energy-element-informational unity $f\,(E,C,I)_{\text{of the biosystem}}$, for example, with other conditions being equal, ***due to growth of the information content*** (studies, education) ***will be large***.

Director of the Institute of Human Brain of RAS S. Medvedev said: Active creative work of the brain increases our lifespan. For example, the

process of creation awakens the brain regions important for the person's emotional activity, including those in hypothalamic structures affecting the endocrine system which is directly connected with the aging processes. Solving of supertasks can cause formation of new connections and generation of new neurons, nerve cells, in the brain of even an elderly person. Length of life of people who throughout their lives have to constantly use their heads is significantly higher compared with those whose brains do not experience any severe stresses. [You Need to Work with Your Head. Komsomolskaya Pravda in Ukraine, January 14-20, 2009.].

Director of the Russian Gerontological Research Center V. Shabalin said: In the Stone Age the average duration of life was 18-20 years. In the Middle Ages it was about 30-40 years. It was only in the late XIX century when the people continued to live to 35 years of age in average, by the end of the XX century the average length of life increased to 70-75 years. That is only in the last century - incredibly fast! - we have begun to live twice as long. ***We*** *are that* ***information base*** *that allows our descendants to move up to a higher level. [The Smart Will Live Up to 150 Years Old and the Lazy Will Become Extinct. Komsomolskaya Pravda in Ukraine. October 9-15, 2009.].*

4. Multidisciplinary System Research

The established and described above laws made it possible to present a qualitative picture of organization of life of the Universe (Fig. 13).

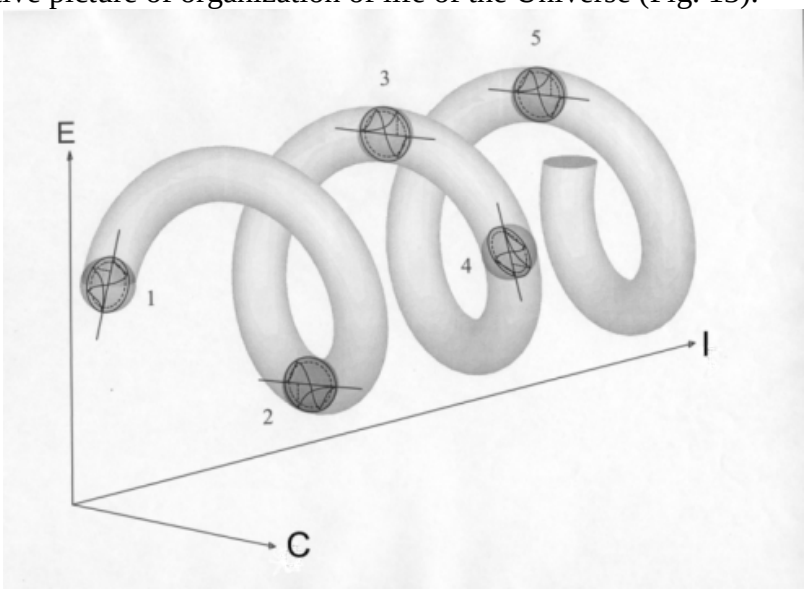


Fig.13. Cyclic change of the function of state $f\,(E,C,I)_{\text{of the Universe}}$ and biosystems 1-5, aligning their equilibrium according to the change of energy-element-informational characteristics of the Universe

Figure 13 shows the cyclic change of energy-element-informational characteristics of the environment occurring during the time that is commensurable with the duration of the existence of successive generations of biosystems. In this case we should talk about alignment of the equilibrium state in each of the generations with a gradual transition from the energy-element-informational properties inherent in system 1 to the energy-element-informational properties inherent in systems 2, 3, 4 and 5 by means of alternation of generations in harmony with changing characteristics of the environment.

A variety of shapes and properties of the wildlife systems is attributable to the variety of possible options for energy-element (H, C, O, N, P, S, Si)-informational conjugations formed and functioning under various constantly changing energy-element-informational conditions of the environment.

We may say that a qualitative picture of life has been drawn. To perform systemic work on quantitative specification of the picture of life it is necessary to unite the efforts of physicists, chemists, materials scientists, biologists, computer scientists, planetary scientists and astronomers within the multidisciplinary project ***"Life. Motion of Energy-Element-Informational Unity of the Matter"***.

Foremost objectives of the Project:

- study of patterns of change of the energy-element-***informational*** unity in the periodic table;

- plotting of discrete diagrams of energy-element-informational state-property of ***helical structures*** on the basis of elements H, C, O, N, P, S, Si (prior-to-DNA structures; physical systems)

- establishment of laws of ***the process*** of change of the energy-element-informational state and hence the properties of systems on the basis of biogenic elements H, C, O, N, P, S, Si (helical DNA structure, cell, organism, biosystems);

- ***modeling***, mathematical specification of the equation of Life, a natural energy – element - informational cyclic process of formation, development and evolution of spiral structures of H, p-elements in the past, present and future lifetime of the Universe.

Conclusions

The important role of *information* as an integral part (along with the matter and energy) of the characteristics of systems, qualitative and quantitative indicators of which *should be considered* to fully cognize and describe the properties of material systems, *biological systems in particular*, has been shown.

A concept of the energy-element-informational function of state *f* (E,C,I) of the matter (nano÷mega level) has been developed (the same for both physical and biological systems).

The regularities of Life have been established and a possibility of modeling of Life as a natural phenomenon organized by moving in space and time energy-element-informational triunity of the Universe has been opened.

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GEOMORPHOLOGICAL CHANGES CAUSED BY THE 2004 TSUNAMI IN THE COASTAL ENVIRONMENT OF WELIGAMA BAY AREA IN SRI LANKA

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Abstract

The coastal area of Weligama bay was severely affected by the tsunami disaster on 26th of December 2004. It has caused thousand deaths in addition to the destruction of million rupees worth properties and also most of the geomorphological features have been changed severely. Therefore, this study was to examine how the tsunami waves have impacted on geomorphological environment of Weligama bay beach area.

Changes of geomorphological features were identified through the analysis of satellite images before 2004 and after in 2005. Arc view GIS software was used to hazardous mapping and damage analysis of the area. Pre and post tsunami map overlay technique of Arcview software can be used to determine the changes of geomorphological features.

The tsunami waves have caused to change coastal features by shrinking and spreading estuaries, eroding the coast and blocking the estuary. Such changes can be observed in the estuaries of Polwatta Ganga, Pemuyana and Rassamuna headlands, and Weligama bay beach. North of the Polwatta Ganga estuary was spreader in about 5 meters and the breath of sand spit of the estuary was increased in about two meters. The Tsunami waves attacked to the Pemuyana headland in the south of the bay occurring serious damaged to the Weligama town area and base of the headland was eroded about one Meter.

The Kapparatota natural harbor which was Located in the northern part of the bay has changed into a bay beach by sand deposition.

Keywords: Tsunami, Geomorpology, Estuary, Headland, Sand spit

Introduction

The coastal area of Weligama Bay is an attractive landscape because of its varieties of Landforms and ecosystems such as beaches, sand spits, estuaries, sea cliffs, headlands mangroves, Marshlands, and corals. Not only the esthetic value of the area, but also they were influenced to establish specific socio economic activities. With the influence of these geomorphological features, many economic activities such as fisheries, tourist and coir processing are located in this area. Landforms and ecosystems caused to control the natural disasters in to some extent, i.e. floods, storm waves. However, after the 2004 tsunami disaster, these geomorphological features in the area were seriously damaged and changed leading to imbalance of the coastal systems.

According to the records of coast conservation Department in 1997, three thousand seven hundred seventy six coastal habitats can be observed in Matara and Galle districts represented of this study area. Most of these resources were completely or partially damaged by the tsunami waves travelled up to 1 Km inland at certain places. It destroyed vegetation, changed landforms, created vast amounts of debris released pollutants and contaminated soils and fresh water supplies. Also, it has created many more environmental problems, such as, coastal pollution, coastal erosion, degradation of landforms and coastal habitats. With the occurrence of the tsunami, these environmental problems in the southern coastal zone have tremendously increased.

Even though, many studies have been paid many attention on examining the human and socio-economic impacts of tsunami, they are not yet satisfactorily addressed the problems concerning the entire environment of the coastal area. A few studies carried out so far have not been paid attention on these sectors in environmental aspects. As such, this has been analyzed the impact of tsunami on geomorphological features of Weligama coastal environment.

1.0 Objectives of the study

The main objective of this study was to examine how the tsunami waves have impacted on coastal geomorphological environment of Weligama bay area. In addition to above major objective, this study concerned on the following aspects,

(a) Identification of geomorphological features within the study area.
(b) Determination of tsunami wave process affected to the geomorphological changes.

(c) Analysis of coastal geomorphological changes on Weligama bay beach.

2.0 The area of study

The area of this study was conducted in the coastal area of Weligama bay stretching from Pemuyana headland to Rassamuna headland. This area represent the Weligama divisional secretariat and it is one of the worst damaged in Matara district. Among the twenty nine Grama Niladari divisions within this divisional secretariat, twenty two G.N.divisions were affected by tsunami.

This area is a densely populated with concentration of many socio-economic activities. As a result of heavily impacted of tsunami on this area, over 282 people lost their lives and 2466 families have been displaced. Five hundred forty three houses completely damaged and also most of the socio-economic activities were vastly damaged. (Ministry of women's Empowerment and social welfare, 2005) In addition there were drastic destructions on coastal landforms and ecosystems of Weligama coast of Sri Lanka. Hence, Weligama coastal zone is selected as the study area covering these specific aspects.

The study area stretching from Pemuyana headland to Rassamuna headland, which is demarcated by mean sea level in the west and tsunami affected boundary line (TABL) in the east. (See fig 01)

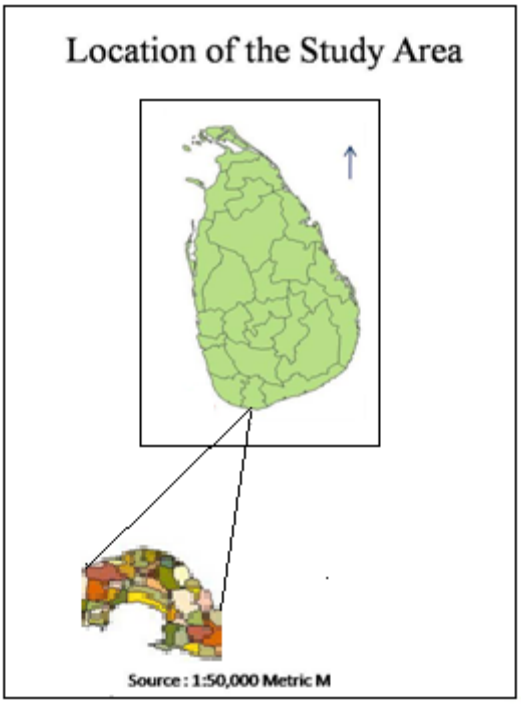


Fig 01-Distribution of the Study Area from Mirissa headland to Rassamuna Headland

3.0 Methodology

Required data for this study have been collected from available primary and secondary sources. For the identification of socio-economic damages in the study area, secondary data was collected from Weligama district secretariat office, Disaster Management Center and senses department in Sri Lanka. To make above mentioned study successful several methods were used to collect the primary data. Tsunami mapping, Questioner survey, target group discussion and field observation were used to relevant data collection.

The magnitude of affected geomorphologic features and ecosystems were identified through the analysis of satellite images before 2004 and after tsunami in 2005. Arcview GIS software was used to hazardous mapping and damage analysis in the area. Pre and after tsunami maps overlay technique of the Arc view software can be used to determine the changes and damages of geomorphological features. Using these data, a tentative geomorphological map was constructed to demarcate the damages and changes of geomorphological units and this was verified through the field works.

4.0 Geomorphological changes of Weligama coastal environment

Weligama bay area which is situated in southern Sri Lanka is very important in geomorpologically and ecologically. This area consists of coastal landforms originated by various kinds of processes. They are bay beaches and allied features, bay and headlands, estuary, beach rocks, alluvial plains, Fluvio-marine plains, denudational hills and planation surfaces. (See fig. 02) These are originated with the influence of marine, fluvial, Fluvio-marine and denudational processes.

Sea is the major agent in landform formation in the study area. It consists of number of marine agents such as waves, currents and tides. In addition, short term and long term sea level changes have affected to form landforms. Sea beaches, bay, islets, sand spits, sea cliff, headlands can be observed within the area originated by marine process.

The fluvial process is the dominant process in creating landforms next to marine process (weerakkody,1990). Polwatta River is the main source of formation of landforms and bringing sediment material to the coast. The amount of material brought through the polwatta ganga, deposited to form to landforms. As a result of these depositions alluvial plains, spits, flood plains are originated.

Some landforms have been originated as a result of admixing marine and fluvial processes. They categorized as flurio-marine process (swan,1983) Fluvio-marine and lagoons are the major fluvio-marine land forms.

Generally, rocks are weathered by chemical, physical and organic action under the influence of climate, relief and morphology. Weathered material transported by water, wind and waves and ultimately deposited in lowlands. They have been caused to erosion and denudate of the surface topographic features (Bird,1976). The denudational landforms consist of denudational hills. planation surfaces and rock out crops.

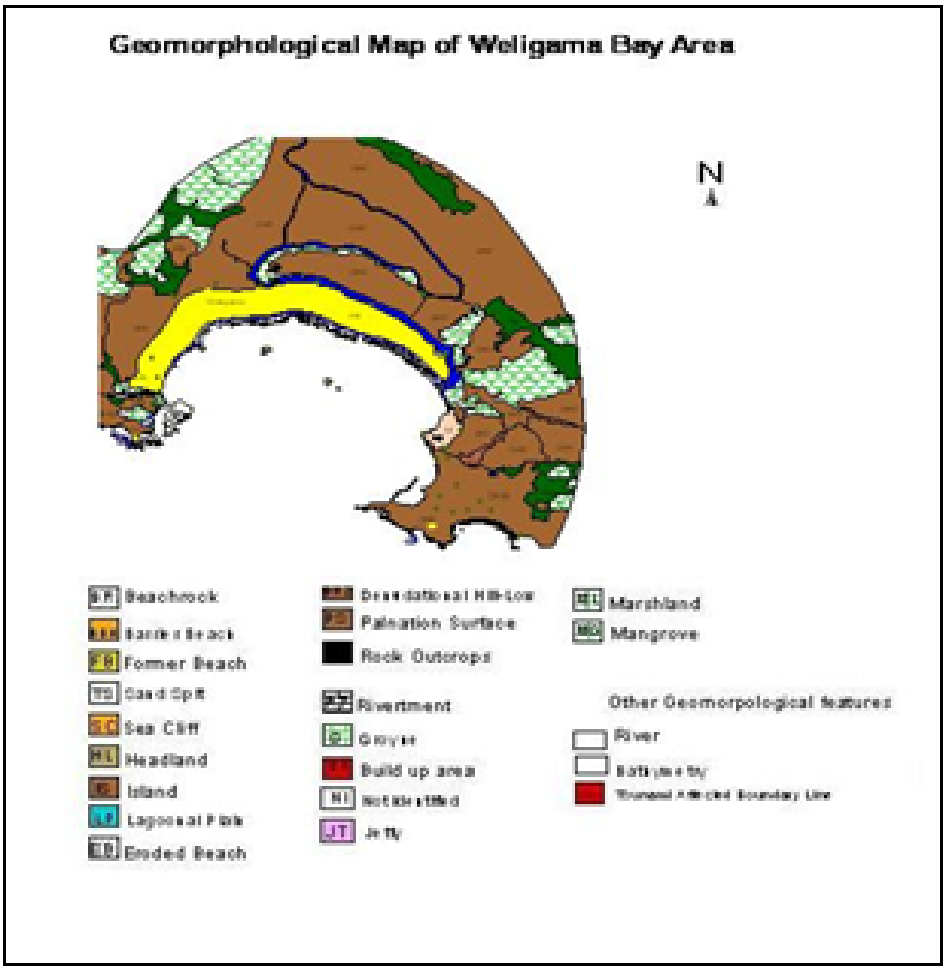


Fig 02-Tsunami affected coastal features in Weligama Bay area.

Human activities have affected on the changes of landforms in the coastal area similar to natural processes. The changes made by engineering constructions are prominent among human activities. Revetments and Groynes are some examples of manmade landforms. Especially eroded coastal area is the Kapapratota best example in the area. They are useful to preserve the coastal environment.

Although these landforms contribute to preserve existing coastal environment, specific landforms were badly damaged completely or partially. Most of them were changed by 2004 tsunami waves. Seventy five percent of total landforms were heavily damaged. Marine landforms of them were highly damaged by the tsunami waves. Bay beach, estuary, sand spits, beach rocks, headlands, sea cliffs and coastal structures are the specific coastal landform which was heavily damaged and changed by tsunami. They

could be identified by the interpretation of pre and post tsunami satellite images using Geographical Information System (GIS) and also they compiled into Geomorphologic maps.(see fig 02)

The tsunami waves have caused to change coastal features by shrinking and spreading of estuaries, eroding the coast and blocking the estuaries. Such changes can be observed in the estuaries of Polwatta ganga, Pemuyana and Rassamuna headlands and Weligama bay beach. The changes of these areas have been studied under the three sections as mentioned below.

(a) Changes of headlands in Weligama bay area
(b) Changes of Polwatta river mouth and sand spits
(c) Changes the coastline of the bay beach

4.1 Changes of headlands in Weligama bay area

The headlands which are located both side of the Weligama bay, are the main geomorphological features affected to the origination of Weligama bay beach. The concave area which is stretched between Pemuyana headland in the south and Rassamuna headland in the north is identified as Weligama bay. The height of these two headlands is 15-30m and they are the main morphological features to change the process of Weligama bay beach. The sea waves which flow into the bay area knocked against these two headlands and it may cause to reduce wave velocity and coastal erosion. Also, it has been a cause to form a broad beach in the area. The location of these headlands has caused to change the tsunami process as well as the normal sea wave process. Although the weligama area had been severely damaged by tsunami, the damaged may be increased further if there were not these two headlands.

The tsunami wave, attacked to the pemuyana headland in the south and it has refracted towards the northwest and north of the bay occurring serious damages to the Weligama town. Also, That is the main reason for the highest damages on Weligama bay beach area. But, there was not highly damage on Pemuyana headland because it is highly mountainous area with 30m in height and it is made of granites rocks. But, base of the headland was eroded about one meter above the sea level and the headland was narrowed because of the erosion of 300 meters of the headlands.

Rassamuna headland in the north of Weligama bay was eroded more than Pemuyana headland. The basement of the sea cliff on Galbokka pocket beach and Gurukanda have been eroded in 15 meters above the sea level because tsunami wave came from westward and waves refracted from the south of the bay, attacked to this headland. The waves which attacked to this headland and they turned into the Galbokka marshland and it was expanded

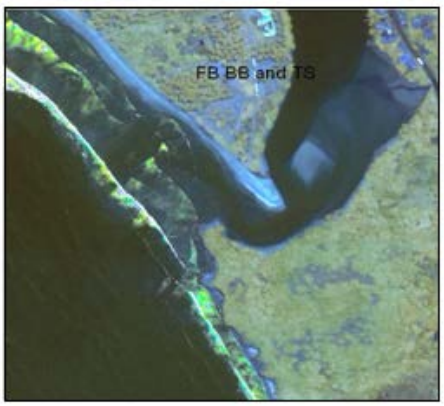
because of stagnant water. However comparing of other geomorphologiacal features, changes of the headlands was not so much.

4.2 Changes of the Polwatta Ganga estuary and sand spit

Polwatta Ganga is the major river flowing across the Weligama bay beach. This river flowing with meandering towards the north of the coastline approaches into the sea, closed to the Pemuyana headland. Estuary, sand spit, sea cliff, mangrove, former beach and beach rocks are the distributed around the Polwatta Ganga estuary and most of them were impacted by the tsunami. Because of the tsunami waves, the estuary was affected with less change. North of the estuary, the breadth was increased in about 5 meters and also, the breadth of sand spit of the estuary was increased in about 2 meters. During the 5000-6000 years Bp, the Holocene sea level went up in 1 meter and created river meanders as a upward movement of the river. (Weerakkody, 1990) Not only has such long-term sea level risen, caused to the coastal changes. According to that, tsunami waves in 2004 have caused to change the Polwatta Ganga estuary.

Tsunami waves have flown 500 meters along the Polwatta Ganga and river meandering obstructed the further flow of water towards the upper areas. Because of this area of river banks sedimented with marine deposits and it damaged the mangroves about the 5 meters breadth along the both river banks.

Sand spit of estuary was developed by tsunami and sand accumulated on flood plain of the both sides of the river banks about in 2 feet thickness. Sand spit was spread in two meters and north of the estuary was broadened in two meters and deepened in one meter. By this time, landscape of the river outfall has become into the former condition, by the redevelopment of sand barrier. But, basement of the sea cliff has been eroded in 15 meters in height, because the tsunami wave attacked on the cliff base. However, the damage of the estuary was less than Weligama bay area as a result of refracted tsunami waves from the Pemuyana headland.



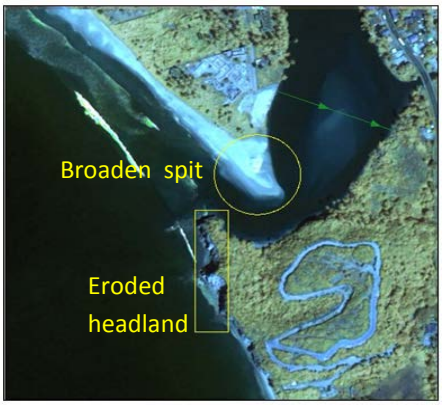


Fig. 03-Polwatta
Ganga estuary-before tsunami

Fig. 04-Changes of Polwatta
Ganga estuary-after tsunami

4.3 Changes of the coastline in the Weligama bay

Weligama coastline stretched from Pemuyana headland to Rassamuna headland is the bay beach area. This coastline with concave shape is a broad flat terrain area. The depth of the coastline sea floor is less than 5 meters and the height of the coastline is not more than 1 meter. This area with flat terrain was severely affected by the tsunami and eroded the coastline in two meters towards the land area, and also the coastline was polluted with accumulation of debris. Buildings and properties were also highly damaged.

The bay was geomorphologically changed because of sand deposition on the north part of it. Tsunami wave refracted towards the north-west of the bay, and the northern part of the bay beach was formed further with beach materials transported by the tsunami waves from south to north direction. It has caused to develop a broaden beach at about 15 meters in width and former offshore coast had changed into a sandy beach now. As a result of this, it is clear that the Kapparatota natural harbor has changed into a bay beach area. (See fig 04 and 05)

Fig. 04-Progradaded beach after tsunami by accumulation of Sand-Kapparatota

Fig. 05-Collected sand deposits from Kapparatota harbor

5.0 Conclusions

The coastal landscape of Weligama has been created with Varity of coastal landforms, originated from processes of marine, fluvial, flurio-marine, winds and denudation. But 75% of them have been impacted by the 2004 tsunami. The bay beach and its allied features such as, headlands, sand spits, sea cliff, marshlands and estuaries were the mostly damaged and changed landforms of the area.

A part from the damages, lots of changes of geomorphologic features could be identified. The changes were broadening, narrowing and blocking of river outfall, broadening and sedimentation of marshlands and sand spits. Such changes can be observed in the estuaries of Polwatta Ganga, Pemuyana and Rassamuna headlands, and Weligama bay beach.

North of the Polwatta Ganga estuary was spreader in about 5 meters and the breath of sand spit of the estuary was increased in about two meters. The Tsunami waves attacked to the Pemuyana headland in the south of the bay occurring serious damaged to the Weligama town area and base of the headlands was eroded about one Meter and they were narrowed because of the erosion of 300 meters of the headlands. Rassamuna headland in the north of Weligama bay was eroded more than Pemuyana headland.

The bay was geomorphologically changed because of sand deposition on the north part of it. As a results of this the Kapparatota natural harbor which was Located in the northern part of the bay has become into a bay beach by sand deposition.

Most of these geomorphologic features were severely changed and very extensive changed has occurred on bay beach, river outfall, sand spits, marshland and headlands.

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