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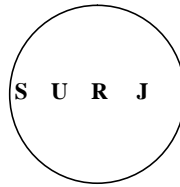
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Lithofacies and Lateral Extension of latest Cretaceous Dinosaur beds from Sulaiman Foldbelt, Pakistan

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Abstract

The Late Cretaceous Pab Formation consists of quartzose sandstone with subordinate muds, deposited on the western continental margin of Indo-Pakistan plate, is well exposed in the Sulaiman and Kirthar foldbelts, and coeval strata like upper part of Lumshiwai and lower part of Hangu Formation are also exposed in the upper Indus basin like Trans Indus, Salt Range, Kohat and Potwar regions. The Pab Formation of Dhaola Range of central Sulaiman foldbelt is divided into three members namely Dhaola, Kali and Vitakri members. Vitakri member is the host of Latest Cretaceous (Maestrichtian) dinosaurs and other archosaurs from Sulaiman fold belt. Vitakri member or dinosaur beds will be used synonymously. Eight lithologic sections have been measured through the upper part of Pab Formation. Out of these, five lithologic sections across strike extent of some 80 km, and four (one is overlapping) lithologic sections along a strike extent of some 250 Km, provide new data on the depositional environments, lateral extension and depositional pattern of Latest Cretaceous dinosaur beds and their coeval sequences in the Sulaiman foldbelt.

The four main facies of Latest Cretaceous strata of upper part of Pab Formation identified in the Sulaiman foldbelt are; Facies F1 (Trough cross and planar laminated/bedded sandstone), Facies F2 (Massive reddish brown to red muds), Facies F3 (Carbonaceous shale) and Facies F4 (Tabular/planner and trough cross bedded sandstone interlayered with the subordinate greenish grey and minor reddish brown muds). These facies formed by a range of sand transporting mechanisms that includes classical meandering and overbank flood flows, oxbow and crevasse splay lakes, storm and river flood generated flows, and high and low energy tractional flows. Three facies associations identified in the upper part of Pab Formation are, meandering river and overbank flood association well exposed in the southern part of central Sulaiman foldbelt, oxbow lake and Crevasse splay lacustrine association found in the Kingri area of northern part of central Sulaiman foldbelt, and alluvial delta fan beach association (mostly submarine and rarely subaerial) located in the Kaha-Harrand section of southern Sulaiman foldbelt and in the Musa Khel and Mughal Kot sections of the northern Sulaiman foldbelt. Facies association patterns demonstrate the existence of three depositional systems in the Sulaiman foldbelt during the Latest Cretaceous. Sandbodies with subordinate muds formed in westward prograding mostly submarine and partly subaerial dominate north and south systems, while the central system like meandering river and associated flood bank, oxbow and crevasse splay lacustrine environments deposited the sandstone, reddish brown muds, coal, carbonaceous shale and green muds in the central part of Sulaiman foldbelt. Quartzose nature of sandstone and paleoflow suggest supply from the uplifting Indo-Pakistan Shield to the eastward. Sediment gravity flow generally evolved from east-west.

The Dinosaur beds/Vitakri beds thickness varying from 15 meter(m) to 35 m, is increasing toward WSW and decreasing ENE directions. The lateral extension of Latest Cretaceous (Maestrichtian) dinosaur beds of the Pab Formation have been observed in major four anticlinoria named as Vitakri-Mari Bohri anticlinorium (Barkhan and Kohlu districts), Dhaola anticlinorium (Barkhan and Kohlu districts), Phulali anticlinorium (Barkhan, Dera Bugti and Kohlu districts) and Fort Munro anticlinorium (Dera Ghazi Khan and Rajan Pur districts). A model of meandering river named as D.G.Khan-Vitakri river forming lobate belt shape, flowing EW from Indian shield to Fort Munro, and flowing ENE to WSW from Fort Munro to Mari Bohri via Vitakri. The exposed strata of dinosaur beds (Vitakri member) of southern part of central Sulaiman foldbelt is surrounded by coeval strata like the lacustrine charged by overbank flood in the near north (Badhi and Kingri), mostly submarine and partly subaerial alluvial delta fan in the farther north (Musa Khel and Mughal Kot area), delta fan and shelf marine in west, delta fan in the south (Kaha-Harrand area), and terrestrial paleoland (and Indo-Pakistan Shield) in the east.

Keywords: Cretaceous dinosaur beds, Sulaiman fold belt, Pakistan.

Introduction

The Late Cretaceous Pab Formation consists of quartzose sandstone with subordinate muds, deposited on the western continental margin of Indo-Pakistan plate, is well exposed in the Sulaiman and Kirthar foldbelts, and its coeval strata like upper part of Lumshiwai and lower part of Hangu Formation are also exposed in the upper Indus basin like Trans Indus, Salt Range, Kohat and Potwar regions. The present study is restricted to the Sulaiman foldbelt of Pakistan (Figure-1). The Pab Formation of Dhaola Range of central Sulaiman foldbelt is divided into three members namely lower Dhaola, middle Kali and upper Vitakri members (Figure-5). Vitakri member (Figure-16) is the host of Latest Cretaceous dinosaurs and other archosaurs from Sulaiman fold belt, Pakistan. Eight lithological sections have been measured through the upper part of Pab Formation. Out of these, five lithological sections across strike extent (Figure-14) of some 80 km, and four (one is overlapping with across strike) lithological sections (Figure-15) along a strikewise extent of some 250 Km, provide new data on the depositional environments, lateral extension and depositional pattern of latest Cretaceous dinosaur beds and their coeval strata in the Sulaiman foldbelt. Facies association and paleoflow patterns demonstrate the existence of three depositional systems (Figure-18) in the Sulaiman foldbelt during the Latest Cretaceous. Sandbodies with subordinate muds formed in westward prograding mostly submarine and partly subaerial dominate north and south system, while the central system like meandering river and associated flood bank, oxbow and crevasse splays lacustrine environments deposited the sandstone, reddish brown muds, coal, carbonaceous shale and green muds in the central part of Sulaiman foldbelt.

Quartzose nature of sandstone and paleoflow suggest supply from the uplifting Indo-Pakistan Shield to the eastward. Sediment gravity flow generally evolved from east to west.

The fluvial lithofacies of central system of Sulaiman foldbelt is the host of following Latest Cretaceous fauna. From first discovery to uptill now round about three thousand fragmentary bones/pieces of bones/fossils have been collected by author from the terrestrial strata of Latest Cretaceous (Maestrichtian) dinosaur bed/Vitakri member of upper part of Pab Formation from Central Sulaiman foldbelt. Pakistani Titanosaurs tails tell five tales. Three genus and species (*Pakisaurus balochistani*, *Sulaimanisaurus gingerichi* and *Khetranisaurus barkhani*) of herbivorous Pakisaurid=Titanosaurid, and two genus and species (*Marisaurus jeffi* and *Balochisaurus malkani*) of herbivorous Saltasaurids are erected (Malkani, 2004a,d). One genus and species (*Vitakridrinda sulaimani*) of carnivorous Abelisaur Theropod established (Malkani, 2004a,d). One genus and species (*Pabwehshi pakistanensis*) of Mesoeucrocodylia are established (Wilson, et al. 2001, Malkani, 2004b). In addition to this, a partial skull (Malkani, 2003a) along with nearby findings of some cervicals, dorsals, caudals and appendicular elements (Malkani, in process) of *Marisaurus*, four armor bones (Malkani, 2003b), one braincase (Wilson, Malkani and Gingerich, 2005), and an atlas-axis complex, (Malkani, in review) have been described. The author also uncovered a Rostrum of *balochisaurus* (Titanosaurian sauropod), a snout of *Vitakridrinda* (Abelisaurian Theropod), an overlapping dentary teeth (partial), and many cervical, dorsal, sacral and caudal vertebrae, and appendicular elements of Pakistani

Titanosaurian sauropod saurishian dinosaurs (Malkani, in process).

One genus and species (*Brohisaurus kirthari*) of Late Jurassic Titanosauria have been discovered from Kirthar foldbelt, Pakistan (Malkani, 2003c).

In this paper reports on the lithofacies, depositional environments and lateral extension of Latest Cretaceous dinosaur beds in Sulaiman foldbelt..

Geological and stratigraphical setting

The study area of Sulaiman fold belt is located in the Central part of Pakistan (Figure-1). Latest Cretaceous (Maestrichtian) dinosaurs are hosted by the Pab Formation of Sulaiman fold belt. The Latest Cretaceous Sediments in the study area underwent considerable tectonic deformation during the collision of Asian and Indo-Pakistan continental plates that commenced in the Late Cenozoic. As a result dinosaur beds along with other formations have been folded. The lateral extension (Figure2)of dinosaur beds of the Pab formation have been observed in the major four anticlinoriums (Figure-4) generally trending NNE to SSW, however the western part of Dhaola and Mari Bohri anticlines trend E-W forming lobate belts. The First, Vitakri-Mari Bohri anticlinorium is located in the Barkhan and Kohlu districts, extended more than 40 km started from Gumbrak in the northeast and running from Vitakri to Makhmar via Mari Bohri plunging in to the Mawand syncline on the west. Actually this anticlinorium consists of two doubly plunging anticline named as Vitaki and Mari Bohri anticlines loacted on the direction of same fold axis. Further north of this anticlinorium, Ber-Fazil Chil and Jandran anticlines trending parralel are located. At the locality of Eastern plunge of Ber-Fazil Chil anticline which is faulted mand thrustted show the sediment gravity flow like igneous

volcano. Previously it is marked as Kohlu Volcano by Bannert, D. *et al.*, (1995). The materials of gravity flow consist of mostly fragments of Pab and Rakhi Gaj formations. The dominant colour of matrix of flow is red to redish brown which may be due to intense faulting and red colour of Vitakri member of Pab Formation. This red colour gives a clue for the dinosaur red beds. The second, Dhaola anticlinorium is located in the Barkhan and Kohlu districts, and extended more than 60km started from Badhi in the northeast and running from Badhi to Chapper via Mazara, Hanki, Ohi, Dhaola, Andhari, and plunging west in the Makhmar area. The third, Phulali anticlinorium is located in the Barkhan, Dera Bugti and Kohlu districts and extended upto 50 km started from Rakhni in the northeast and running from Phulali to Siah Koh via Pikal. This anticlinorium consists of three doubly plunging anticlines named as Phulali, Pikal and Siah Koh anticlines with same trend of fold axis. The fourth, Fort Munro anticlinorium is located in the Dera Ghazi Khan and Rajan Pur districts, and extended more than 70 km started from Sori Lund Rud in the NNE and running from Shadani to Kalchas via Mithwan, Anari-Fort Munro, Choti Nala, Kan, Chitri, Dragal /Ziarat Sheru, Kaha and Mari.

The Sulaiman foldbelt consists of sedimentary rocks ranging in age from Jurassic to Recent (Figure-3). The rocks comprising of shale, limestone, sandstone, siltstone, marl and conglomerate in different lithological units in ascending order as; Jurassic Sulaiman group representing Spingwar, Loralai and Chiltan formations, Cretaceous Parh group representing Sember, Goru and Parh formations, newly proposed Fort Munro group representing Mughal Kot, Fort Munro and Pab formations; Paleocene Ranikot

Group representing Khadro, Rakhi Gaj and Dungan formations; Eocene Ghazij Group represents Shaheed Ghat, Toi, Drug and Baska formations; (newly proposed) Kirthar group represents Habib Rahi, Domanda, Pir Koh and Drazinda formations, Oligocene-Pliocene Vahoa

(newly proposed) group represents Chitarwata, Vahoa, Litra and Chaudhwan formations, Pleistocene Dada Formation, Subrecent and recent fluvial, eolian and colluvial deposits (Malkani, 2004c) (Figure-3, Table-1).

Table-1; STRATIGRAPHIC SEQUENCE OF SULAIMAN FOLDBELT

<u>Age</u>		<u>Formation</u>	<u>Lithology</u>	
Q U A T E R N A R Y	Recent	Modern channel deposits	Gravel, sand, silt and clay	
		Sand, silt and clay deposits (cultivated lands)	Sand, silt and clay with minor gravel	
	and	Sand, silt and clay deposits (non-cultivated lands)	Sand, silt and clay with minor gravel	
		Colluvium deposits	Boulder, pebbles, cobbles, with sand silt and clay.	
		Fan gravel deposits	Poorly consolidated gravel, sand, silt and clay.	
	Sub-Recent	Terrace gravel deposits	Poorly consolidated gravel, sand, Silt and clay.	
	----- Angular Unconformity -----			
		Pleistocene	Dada Formation	Conglomerate, sandstone and clays.
	----- Angular Unconformity -----			
	T E R T I A R Y	Pliocene	Chaudhwan Formation	Clays, conglomerate and sandstone
Litra Formation			Sandstone, clays and conglomerate	
Miocene		Vihova Formation	Clays, sandstone and conglomerate	
		Chittarwata Formation	Clays, conglomerate and sandstone	
Oligocene		-----Disconformity-----		
		Drazinda Formation	Shale with minor coquina.	
		Pir Koh Formation	Limestone, marl and shale.	
		Domanda Formation	Shale with minor coquina and gypsum.	
		Habib Rahi Formation	Limestone, marl and shale.	
		Baska Formation	Gypsum, shale with minor salty dolomite.	
	Drug Formation	Rubby limestone and mudstone / shale.		
	Toi Formation	Sandstone, shale, rubby limestone and coal.		
Shaheed Ghat Formation	Mainly shale with minor marl / limestone and siltstone.			
Paleocene	Dungan Formation	Limestone, marl and shale		
	Rakhi Gaj Formation	Shale, mudstone, siltstone, sandstone & limestone		
	Khadro Formation	Limestone with minor shale and sandstone		
	-----Disconformity-----			
C R E T A C E O U S	Late	Pab Formation	Sandstone with subordinate shale	
		Fort Munro Formation	Limestone, shale and coquina beds	
		Mughal Kot Formation	Shale with minor marl/limestone and coquina beds	
	Early	Parh Formation	Limestone with minor marl and shale	
		Goru Formation	Shale and marl with minor limestone	
		Sembar Formation	Mainly shale with minor marl and mudstone	
		-----Disconformity-----		
	Middle	Chiltan Formation	Mainly Limestone.	
		Loralai Formation	Limestone with insignificant shal	
		Spingwar Formation	Shale, marl and limestone.	
Early				

Previous investigations

Late Cretaceous Pab Formation is well exposed in the Sulaiman and Kirthar fold belts of Pakistan. Previous pioneer worker who described the Lithofacies and depositional environments of Pab Formation include Khan, *et al.*, (2002), Warwick, *et al.*, (1995), Sultan (1997), and Malkani, (2003b). Khan, *et al.* (2002), described the lithofacies and depositional environments of Mughal Kot and Pab formations of Pab Range and its northern extension up to Karkh area of Kirthar Range. Khan *et al.* (2002) argued that facies association and paleoflow patterns demonstrate the existence of two depositional systems in the central Kirthar area during the Late Cretaceous. Sandstone formed in a NW-prograding submarine fan dominate a southern system, while in the north the storm and river flood influenced shelfal sands were conveyed to the west and WNW. The shore face environment was assigned in the northern part (Karkh area) of central Kirthar foldbelt. Warwick, *et al.*, (1995) described the lithofacies of some Cretaceous and Paleocene rocks in Surghar and Salt Range coalfields.

Sultan, (1997) reported that the Pab Formation of Sulaiman foldbelt attain the thicknesses ranging up to 400 meter and are dominated by quartzose sandstone with minor muds, which were deposited on the western continental margin of the Indo-Pakistan plate. In the western part of the Sulaiman Province, the formation is marginal marine to fluvial. Fluvial deposits include cycles of fining upward grain size, poor sediment sorting, decreasing upward bed thickness, trough cross bedding, reddish brown overbank deposits, and silty to muddy matrix in upper parts of Pab Sandstone. Sultan (1997) assigned Pab Formation dominantly upper shore face environments, with subordinate fluvial,

lagoonal, estuarine, and lower shoreface facies.

Malkani, (2003b) assigned the fluvial origin of uppermost part of Latest Cretaceous Pab Formation in the central Sulaiman foldbelt. The Pab Formation of Vitakri region has been divided into three members. The lower member is named as Dhaola member (Dhaola means white) which mainly consists of white, light brown, whitish grey, thin to thick bedded, fine to coarse grained and poorly sorted quartzose sandstone. The type locality of this member is Dhaola Nala (Grid reference; 29° 42' 41'' N, 69° 29' 48'' E). The middle member is named as Kali member (Kali means black) represents white, light brown, whitish grey, thin to thick bedded, fine to coarse grained, muddy matrix and poorly sorted quartzose sandstone with cyclic alternations of greenish grey to reddish brown mudstone. The matrix of Kali member is more muddy and ferruginous representing black desert varnish than Dhaola member. The type locality of Kali member is designated the southeast of Gumbrak village located in the northern flank of Dhaola anticlinorium (Grid reference; 29° 42' 41'' N, 69° 29' 42'' E). The upper member named as Vitakri member/dinosaur beds, is the host of dinosaurs and other archosaurs, consists of red, greenish grey mudstone with cyclic alternations of white, whitish grey to light brown, poorly sorted quartzose sandstone and conglomerate with a muddy matrix. The type locality (Grid reference; 29° 41' 19'' N, 69° 23' 02'' E) of Vitakri member is the Vitakri village. It is well exposed in the east and southeast of Vitakri (Figure 6). The host rock of dinosaurs and other archosaur fossils is the reddish brown muds of the Vitakri member, represents fluvial continental/terrestrial (meandering river and over bank system) environments Sandstone beds represents as channel fill

deposits and red brown mud/clay of over bank deposits. Fluvial environment (Figure 19) is interpreted on the basis of vertebrate fossil (dinosaurs and crocodiles) assemblages, absence of marine fauna, red and brown mud, iron concretions and calcrete found in the over bank mud/clay horizons; trough cross and planner bedding/lamination, poor sediment sorting and muddy matrix found in the channel fill sandstone. Generally three fining upward sequences (sandstone and mud/clay), starting from topmost sandstone of Kali member, passing through Vitakri member to lower Khadro shale are found in the central Sulaiman flodbelt.

Materials and methods

Most of the data presented here have been obtained from measured stratigraphic columnar logs at eight localities in the Sulaiman flodbelt (Figure 6-13, 19), supplemented by observations made in the field. Field work was done in the Sulaiman fold belt for about one month during early 2005. The measured sections of dinosaur beds include lithologic log of dinosaur beds in Mari Bohri area, eastern plunge of Mari-Bohri anticline (Figure-6), lithologic log of dinosaur beds in Kinwa Kali Kakor locality of Vitakri area (Figure-7,16), and lithologic log of dinosaur beds in Basti Nala(Zubra) area, north western limb of Dhaola anticlinorium (Figure-8), Barkhan district, Balochistan; lithologic log of dinosaur beds in Khar-Fort Munro area (Figure-9) and lithologic log of dinosaur beds in Rakhi Gaj area (Figure-10), Dera Ghazi Khan District, Punjab Province. Other measured sections of coeval strata of dinosaur beds include lithologic log of upper part of Late Cretaceous Pab Formation in Kaha-Harrand area (Figure-11), Rajan Pur district, Punjab, lithologic log of upper part of Late Cretaceous Pab Formation in Kingri area (Figure-12), and

lithologic log of upper part of Late Cretaceous Pab Formation in Hazarghat/Musa Khel area (Figure-13) of Musa Khel district, Balochistan. Correlation chart of dinosaur beds across strike (Figure-14) and correlation chart of dinosaur beds and coeval strata along strike wise (Figure-15) in the Sulaiman flodbelt have been prepared. Stratigraphic correlations between the sections were made by using the best fit method. Paleoflow directions were tentatively known from the cross bedding and in situ occurrences of some dinosaur fossils.

Lithofacies of latest cretaceous strata of upper part of pab formation in sulaiman fold belt.

Eight representative lithologic sections through the Latest Cretaceous strata of upper part of Pab Formation in the Sulaiman flodbelt have been measured (Figure 6-13). The four main facies of Latest Cretaceous strata of upper part of Pab Formation are identified in the Sulaiman flodbelt on the basis of lithology, grain size, fossil occurrences and internal sedimentary structures. These Four facies are; Trough cross and planner laminated/bedded sandstone; Massive reddish brown to red muds; Carbonaceous shale; and Planner/tabular and trough cross bedded sandstone interlayered with the subordinate greenish grey and minor reddish brown muds. These facies formed by a range of sand transporting mechanisms that includes classical meandering and overbank flood flows, oxbow and crevasse splays lakes, storm and river flood generated flows, and high and low energy tractional flows.

Facies F1 (Trough cross and planner laminated/bedded sandstone)

The Facies F1 belongs to the Vitakri member/Dinosaur beds and uppermost

part of middle Kali member of Pab formation (Figure 14). This facies is confined to the southern portion of central Sulaiman foldbelt. This facies is characterised by white, whitish grey, thin to thick bedded, fine to coarse grained, quartzose, poorly sorted, laminated to planar bedded and trough cross bedded sandstone (Figure-17). The thickness of every sandstone units vary from 2m to 8m. The base of the small scale trough cross bedded cosets in lenticular fine sandstone are irregular, displaying shallow scouring in to underlying parallel laminated fine sandstone. The top of the small scale trough cross bedded cosets in lenticular fine sandstone are smooth and even with the parallel laminated fine sandstone (Figure-17). This facies have basal thin lag conglomerate.

Interpretation

This facies was deposited under high energy fluvial condition by meandering river induced flows. This meandering river develop laterally restricted, effectively channelled paths from Indo-Pakistan shield to sea. Basal lag conglomerate help the criteria for channel deposition by meandering river. These conditions are well established in Late Tertiary to modern Indus river basin in Pakistan. Small scale trough cross bedding cosets and associated basal and upper parallel laminations(Figure-17) represents interesting depositional history. The parallel laminations developed at the bottom of the low scale trough cross beds represents a plane bed phase of upper flow regime transport at high flood velocity. When current velocity diminished into the lower flow regime at the time of waning flood stage, ripple cross lamination/ trough cross bedding formed on top of the plane lamina with some scouring. A later flood pulse deposited upper flow regime plane beds on top of the ripple cross

lamination/ trough cross bedding (Figure-17). This coarse strata as sandstone is deposited as channel deposits by lateral accretion process.

Facies F2 (Massive reddish brown to red muds)

The Facies F2 belongs to only dinosaur beds/ Vitakri member of the upper part of the Pab Formation, is the host of Latest Cretaceous dinosaurs(Figure 14, 18). This facies is confined to the southern part of central Sulaiman foldbelt. This facies F2 varying in thickness from 2-15 meters(m.) consists of red to reddish brown, greenish grey, massive mudrocks having dinosaur fossils, ferruginous concretions and calcretes.

Interpretation

This facies was deposited on overbank flood flows under high energy fluvial condition by meandering river. The red colour of muds, occurrence of dinosaur fossils, and ferruginous concretions represents overbank flood deposits. The alternation of relatively thick red muds with the sandstone represents overbank and channel deposition respectively. The fine strata as red mud is deposited as flood plain vertical accretion process. The sandstone unit is formed by lateral accretion of channel sand bars.

Facies F3 (Carbonaceous shale)

The Facies F3 belongs to the uppermost part of of Pab Formation and confined to Kingri and its vicinity in the northern portion of the central Sulaiman foldbelt. This facies is characterised by blackish grey/ dark grey to greenish grey shale (Figure 12,15). It also consists of poor grade coal in the Kingri area. Carbonaceous shale have two cyclic alternations with facies 1. The thickness of every cycle of carbonaceous and grey

shale vary from 2m to 8 m. It is thin in the Badhi area and thick in the Kingri section. Babhi area is located near the Rakhni.

Interpretation

This facies was deposited under lacustrine conditions representing oxbow lake and crevasse splay lake in the Badhi and Kingri areas. This facies is interlayered with facies F1. Here Facies F1 represents lateral accretion of meandering channel.

Facies F4 (Tabular/planner and trough cross bedded sandstone interlayered with the subordinate greenish grey and minor reddish brown muds)

The Facies F4 belongs to the upper part of of Pab Formation and confined to the northern and southern part of Sulaiman foldbelt (Figure 11, 13). This facies is also well exposed just below the Facies association 1 in the southern portion of central Sulaiman foldbelt, just below the Facies association 2 in northern portion of central Sulaiman foldbelt. This facies is characterised by white, whitish grey, thin to thick bedded, fine to coarse grained, quartzose, poorly sorted and tabular/planner and trough cross bedded sandstone, and greenish grey to grey shale with minor reddish brown muds.

Interpretation

The facies F4 was deposited under high energy fluvial condition by storm and river flood generated flows, high and low energy tractional flows. Sandstone with opposing planner cross bedded show the reversal tidal beach environments. The opposing planner cross bedding represents the bimodal paleocurrent direction possibly produced by ascending and descending tides. The occurrence of the minor reddish brown muds represents

subaerial part of deltafan. The sandstone with grey muds represents submarine part of deltafan.

Depositional environments of latest cretaceous strata of upper part of pab formation in sulaiman fold belt

First of all I would like to describe the some general terms of sedimentary structures. Tabular cross bedding consists of cross bedded units that are broad in lateral dimensions with respect to set thickness and that have essentially planar bounding surfaces. Trough cross bedding consists of cross bedded units whose bounding surfaces are curved. Tabular cross bedding is formed mainly by the migration of large scale ripples (and dunes). Individual beds range in thickness from a few tens of centimeters to a meter or more, but bed thickness up to 10 meter can be formed (Harms et. al., 1975). Trough cross bedding can originate both by migration of small-scale ripples which produce small scale cross-bed sets and large-scale ripples which produce large scale cross-bed sets. Ripple cross lamination (climbing ripples) forms when deposition takes place very rapidly during migration of current or wave ripples. A series of cross laminae are produced by superimposing migrating ripples. The formation of ripple cross lamination appears to require an abundance of sediment, especially sediment in suspension which quickly buries and preserves original rippled layers. Abundant suspended sediment supply must be combined with just enough of laminae from the stoss side of ripples. Some ripple laminae may be in phase (one ripple crest lies directly above the other), indicating that the ripples did not migrate. In phase ripple laminae form under condition where a balance is achieved between traction transport and sediment supply so that ripples do not migrate despite a growing sediment

surface. Ripple cross lamination occurs in sediments deposited in environments characterised by rapid sedimentation from suspension (Fluvial flood plains, point bars, river deltas subject to periodic flooding, and environments of turbidite sedimentation. The parallel laminations developed at the bottom of the low scale trough cross beds represents a plane bed phase of upper flow regime transport at high flood velocity. When current velocity diminished into the lower flow regime at the time of waning flood stage, ripple cross lamination/ trough cross bedding formed on top of the plane lamina. A later flood pulse deposited upper flow regime plane beds on top of the ripple cross lamination/ trough cross bedding. Ripples provide information about sedimentary processes and paleocurrent direction but they are not unique indicators of depositional environments. Cross bedding formed primarily by migration of ripples and dunes (Boggs, S. J., 1995).

Flaser bedding is a type of ripple bedding in which the streaks of mud occur between sets of cross laminated sandy or silty sediment. Mud is concentrated mainly in the ripple trough but may also partly cover the crests. Flaser bedding suggests deposition under fluctuating hydraulic conditions. Period of current activity, when traction transport and deposition of rippled sand take place, alternate with periods of quiescence, when mud is deposited (Reineck and Singh, 1980). Lenticular bedding is a structure formed by interbedded mud and ripple cross laminated sands when condition is suitable for sand deposition. Hummocky cross-stratification is characterised by undulating sets of cross-laminae that are both concave up (swales) and convex up (hummocks) represents marine conditions. Alluvium is mostly deposited by meandering and braided streams. Meandering river having a

single major channel showing high sinuosity and Braided river have network of channels showing low sinuosity (Boggs, S. J., 1995). Groove marks represents marine and fresh water environments.

Facies Associations

Three facies associations are identified from the above mentioned four main facies F1-F4 of the Latest Cretaceous strata of upper part of Pab Formation in the Sulaiman foldbelt. First facies association (FA1) is meandering river and overbank flood association, is well exposed in the southern part of central Sulaiman foldbelt. Second facies association (FA2) is oxbow lake and Crevasse splays lacustrine association is found in the Badhi and Kingri areas, of northern part of central Sulaiman foldbelt. Third facies association (FA3) is alluvial delta fan beach association (mostly submarine and rarely subaerial), is diagnosed in the Kaha-Harrand section of southern Sulaiman fold belt, and Musa Khel and Mughal kot areas which are located in the northern Sulaiman foldbelt.

Facies Associations FA1 (Meandering river and overbank flood association)

Facies Associations FA1 (Meandering river and overbank flood association) consists of facies F1 (trough cross and planar laminated/bedded sandstone) and facies F2 (relatively thick red muds). Facies Associations FA1 is located in the southern part of central Sulaiman foldbelt. This Facies Associations FA1 represents meandering river and overbank flood deposition. The three fining upward sequences are observed in the latest Cretaceous strata (Figure 6-13). This is the classic fining upward sequence in a meandering river deposit. The lower coarse bed represents channel

deposits formed by point bar lateral accretion process and upper fine mud (red) represents overbank vertical accretion deposits. The cyclic alternations of facies F1 which consists of trough cross bedded sandstone represents deposition by meandering river and facies F2 which consists of relatively thick muds represents overbank flood environments. This facies association represents the most proximal environmental setting identified in the study area. This facies association occurs only in the southern part of central Sulaiman foldbelt, surrounded by lake in the near north (Badhi and Kingri), mostly submarine and partly subaerial alluvial deltafan in the farther north (Musa Khel and Mughal Kot area), deltafan and shelf marine in west, deltafan in the south, and terrestrial paleoland and Indo-Pakistan Shield in the east. (Figure-18).

Facies Associations FA2 (Oxbow lake and Crevasse splays lacustrine association)

Facies Associations FA2 (Oxbow lake and Crevasse splays lacustrine association) consists of facies F3 (Carbonaceous shale) and confined in the Badhi and Kingri areas, northern part of central Sulaiman foldbelt. This Facies Associations FA2 represents over bank flooding of meandering river and shifting the load in to lake. The three fining upward sequences are observed in the latest Cretaceous strata. These are the classic fining upward sequences observed in the Kingri and Badhi areas. Kingri and Badhi areas show cyclic alternations of carbonaceous shale and sandy beds. Sandy beds represent channel deposition while carbonaceous shale, coal and greenish grey muds represent overbank flooding in the lakes which have carbonaceous source like plants. The lower sandy beds represents channel deposits formed by point bar lateral

accretion process and upper carbonaceous dark shale and grey muds represent vertical accretion overbank flooding and vertical accretion deposits.

Facies Associations FA3 (Alluvial delta fan beach association mostly submarine and rarely subaerial)

Facies Associations FA3 (Alluvial delta fan beach association mostly submarine and rarely subaerial) consists of facies F4 (Tabular/planner and trough cross bedded sandstone interlayered with the subordinate greenish grey and minor reddish brown muds). Facies Associations FA3 is located in the Kaha-Harrand section which is located in the southern Sulaiman foldbelt; and Musa Khel and Mughal kot areas which are located in the northern Sulaiman foldbelt. This facies association FA3 represents alluvial deltafan shore face beach association (mostly submarine and rarely subaerial) and tidal effect. This facies association represents the distal environmental setting identified in the study area.

Lateral and vertical extension of dinosaur beds in sulaiman fold belt

Facies associations demonstrate the existence of three laterally variable depositional systems in the Sulaiman foldbelt during the Latest Cretaceous. Sandbodies with subordinate muds formed in westward prograding mostly submarine and partly subaerial dominate north and south systems, while in the central part of Sulaiman foldbelt, the meandering river and associated flood bank, oxbow and crevasse splays lacustrine system deposited the sandstone, reddish brown muds, coal, carbonaceous shale and greenish grey muds. The Dinosaurs and associated other archosaurs found from the southern part of central Sulaiman foldbelt (Figure

2), belong to central meandering river and overbank system. Meandering river and overbank flooding system is also responsible for the oxbow lake or Crevasse splays lacustrine environments exposed in the Kingri and Badhi areas located in the northern part of central Sulaiman foldbelt. The coeval southern system represented by alluvial deltafan beach association (mostly submarine and rarely subaerial), is interpreted in Kaha-Harrand section of Southern Sulaiman foldbelt. The coeval northern system represented by alluvial deltafan beach association (mostly submarine and rarely subaerial), is exposed in the Musa Khel/Hazar Ghat section and Mughal Kot area (Figure-18).

The Dinosaur beds/Vitakri member thickness varying from 15 meter(m) to 35 m, is increasing toward WSW and decreasing ENE directions. Dinosaurs and other archosaurs are hosted by Vitakri member. The lateral extension of dinosaur beds of the Pab Formation have been observed in major four anticlinorium (Figure 4) named as Vitakri-Bohri anticlinorium (Barkhan and Kohlu districts), Dhaola anticlinorium (Barkhan and Kohlu districts), Phulali anticlinorium (Barkhan, Dera Bugti and Kohlu districts) and Fort Munro anticlinorium (Dera Ghazi Khan and Rajan Pur districts). A model of meandering river named as D.G.Khan-Vitakri river forming lobate belt shape, flowing EW from Indian shield to Fort Munro, and flowing ENE to WSW from Fort Munro to Mari Bohri via Vitakri. The exposed strata of dinosaur beds (Vitakri member) of southern part of central Sulaiman foldbelt is surrounded by coeval strata like the lacustrine charged by overbank flood in the near north (Badhi and Kingri), mostly submarine and partly subaerial alluvial deltafan in the farther north (Musa Khel and Mughal Kot area), deltafan and shelf

marine in west, deltafan in the south (Kaha-Harrand area), and terrestrial paleoland (and Indo-Pakistan Shield) in the east (Figure 18).

No simple and consistent vertical facies trend has been identified in the rocks of Sulaiman foldbelt. The Jurassic Sulaiman group and early Cretaceous Parh Group represents fine pelagic and shallow marine deltaic environments, and the Late Cretaceous Mughal kot Formation represents muddy to sandy shelf and distal deltaic environments. The Late Cretaceous Pab Formation of Dhaola Range is divided generally in to three member as lower member named as Dhaola, middle member named as Kali and upper member named as Vitakri (Figure-5). Dhaola member consists of mainly white, thin to thick bedded, poorly sorted quartzose sandstone. The most common sedimentary structure of lower/Dhaola member is the opposing planar/tabular cross beds may showing the tidal reversals in alluvial deltaic environments. Middle member named as Kali (Kali is a local word mean black), is represented by black weathering on this member which is comparatively more common than lower Dhaola member. Kali member represents white, light brown, whitish grey, thin to thick bedded, fine to coarse grained, muddy matrix and poor sorted quartzose sandstone having relatively high black desert varnish than lower member. In the type locality of Kali member many cycles of shale alternation with relatively thick sequence of sandstone are observed. A wood log has been found in the middle of Pab Formation of the Goz Wanga Pass area. The common sedimentary structure of middle/Kali member is the opposing planar cross beds/tabular beds may showing the tidal reversals in alluvial deltaic environments. The truncated flat bedding and cleaned quartzose sands in the Dhaola member and partly in Kali

~~member~~ ~~Malka~~ present the beech environments.

The upper member named as Vitakri member is the host of dinosaur and that is the reason it is used synonymous as Dinosaur beds. Vitakri member represents fluvial meandering river and over bank system. It consists of red , green mud with subordinate whitish grey to white, poorly sorted, trough cross bedded, planner cross bedded, muddy matrix to quartzose sandstone and minor lag conglomerate(graded bedded). This is the classic fining upward sequence in a meandering river deposit. The fine strata as red mud is deposited as flood plain vertical accretion process. The sandstone on the top of Dinosaur beds is thin to thick bedded, slightly calcareous to non calcareous and soft and poorly sorted and have ferruginous nodules and brown rusty weathering on bivalve fossils.

The northern part of central Sulaiman foldbelt like the Kingri section (Figure 12) shows the lake deposits consisting of fine silt and mud introduced in to lakes from the main stream during overbank flooding. They are commonly well laminated and contain carbonaceous matter of plant remains. The carbonaceous content of Kingri section is too much high than Badhi section. The lithologic logs in the southern part of central Sulaiman foldbelt represent the three fining upward sequences representing cyclic alternation of trough-cross bedded sandstone with three cyclic alternation of mudstone facies which are started from uppermost Kali member, to lower Khadro Formation, through Vitakri members, are observed in the Central Sulaiman foldbelt. The lower coarse bed represents channel deposits formed by point bar lateral accretion process and upper fine mud(red) represents overbank vertical accretion deposits. So far Vitakri member is confirmed as dinosaur host, that is the reason the detailed work has

been done on this upper part of Pab² Formation. During early Paleocene the transgression of sea happened which deposited the carbonate shallow marine limestone and shale(fossil bearing like bivalves, nautiloids and gastropods) of Khadro Formation which is followed by the deltaic siliciclastic Rakhi Gaj Formation and shallow marine carbonate Dungan Formation.

Conclusions

Four main facies, three facies associations and three depositional systems have been identified in the upper part of Pab Formation in the Sulaiman foldbelt. The four main facies of Latest Cretaceous strata of upper part of Pab Formation identified in the Sulaiman foldbelt are; Facies F1 (Trough cross and planner laminated/bedded sandstone), Facies F2 (Massive reddish brown to red muds), Facies F3 (Carbonaceous shale) and Facies F4 (Tabular/planner and trough cross bedded sandstone interlayered with the subordinate greenish grey and minor reddish brown muds). These facies formed by a range of sand transporting mechanisms that includes classical meandering and overbank flood flows, oxbow and crevasse splays lakes charged by overbank flooding, storm and river flood generated flows, and high and low energy tractional flows. Three facies associations identified in the upper part of Pab Formation are, meandering river and overbank flood association well exposed in the southern part of central Sulaiman foldbelt, oxbow lake and Crevasse splays lacustrine association found in the Kingri area of northern part of central Sulaiman foldbelt, and alluvial deltafan beech association (mostly submarine and rarely subaerial) located in the Kaha-Harrand section of southern Sulaiman foldbelt and in the Musa Khel and Mughal Kot

sections of the northern Sulaiman foldbelt.

Facies associations demonstrate the existence of three depositional systems in the Sulaiman foldbelt during the Latest Cretaceous. Sandbodies with subordinate muds formed in westward prograding mostly submarine and partly subaerial systems dominate north and south systems. While in the central part of Sulaiman foldbelt, the meandering river and associated flood bank, oxbow and crevasse splays lacustrine systems deposited the sandstone, reddish brown muds, coal, carbonaceous shale and green muds. Quartzose nature of sandstone and paleoflow suggest supply from the uplifting Indo-Pakistan Shield to the eastward. Sediment gravity flow generally evolved from east-west.

The depositional system of Dinosaur Beds interpreted as meandering river and overbank flood deposits in southern part of central Sulaiman foldbelt, associated coeval strata like oxbow and crevasse splays lacustrine deposits of northern part of central Sulaiman foldbelt. Meandering channel deposits are diagnosed on the basis of relatively thin sand with cyclic alternations of thick muds, trough cross lamination/bedding, parallel lamination, muddy matrix and basal lag conglomerate. The overbank flood deposits are diagnosed on the basis of red muds, having ferruginous concretions, calcretes and archosaur bones. The top of dinosaur beds are assumed as K-T boundary. The lateral extension of dinosaur beds of the Pab formation have been observed in major four anticlinoria named as Vitakri-Mari Bohri anticlinorium (Barkhan and Kohlu districts), Dhaola anticlinorium (Barkhan and Kohlu districts), Phulali anticlinorium (Barkhan, Dera Bugti and Kohlu districts) and Fort Munro

anticlinorium (Dera Ghazi Khan and Rajan Pur districts).

A model of meandering river named as D.G.Khan-Vitakri river forming lobate belt shape, flowing EW from Indo-Pakistan Shield to Fort Munro, and flowing ENE to WSW from Fort Munro to Mari Bohri via Vitakri (Figure 18). The exposed strata of dinosaur beds of southern part of central Sulaiman foldbelt is surrounded by coeval strata like the lacustrine charged by overbank flood in the near north (Badhi and Kingri), mostly submarine and partly subaerial alluvial deltafan in the farther north (Musa Khel and Mughal Kot area), deltafan and shelf marine in west, deltafan in the south, and terrestrial paleoland (and Indo-Pakistan Shield) in the east.

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Evaluation of an Advertising Budget, a Game Theoretical Model

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Abstract

This paper describes a two opponents non-zero sum game model for advising a group of cellular companies to economize their expenses uplift profits and increase market share. Various confines and assumptions form the basis of this model; let each company of the group provide similar facilities and essential of these being rigid demand both these groups must have identical cost and related price structure. This model is likely to lay down a basis for a more comprehensive modeling.

Keywords: game theory, saddle point

Introduction

We were approached by two different groups of cellular companies with the intention to launch their services in the country. One group was using AMPS (Advance Mobile Phone System) technology while the other GSM (Global System for Mobile) technology. The marketing trend and advertising play a key role in the financial decision making. Although a definite conclusion implies that money spending at appropriate time (quarterly, biannual or annual basis) and in right direction is the focus of capturing market share and increase clientele appreciably.

In this model we restrict each company of the group to provide same facilities, and strictly demand that both competitors have equal opportunities, ignoring other factors for smoothness and considering that uplift of profit and clientele of a specific group depends only on the expenses incurred by both the groups.

For allocation of advertising expenditure, Friedman (1958) proposed an economic model and Brams and Davis (1973) proposed a presidential election campaign model as a game theoretic point of view. Shane (1977) developed Friedman's model for two companies competing in a market in which demand is fully rigid and market is initially divided between only two competitors. We consider here a model that underlines the effect of advertising expenses on share (number of customers) of a group in a competitive condition and ask it about the size of advertising budget in order to maximize profits. In the model we assume that we have only two competing groups GSM and AMPS.

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The Model

Let

S_1 : Current share of GSM group in the market

S_2 : Current share of AMPS group in the market

S_1^* : Expected share of GSM group in next quarter

S_2^* : Expected share of AMPS group in next quarter

X : Expenditure for advertisement by group GSM

Y : Expenditure for advertisement by group AMPS

n : Total number of current cellular phone users

n^* : Total number of expected cellular phone users in next quarter

In observance Shane (1977) and Khan (2003) the expected share for both groups in the market respectively is

$$S_1^* = S_1 + \frac{(x - y)}{(x + y)} S_1 S_2 \quad \text{-----(A)}$$

and

$$1 - S_1^* = S_2^* = S_2 + \frac{(y - x)}{(y + x)} S_1 S_2 \quad \text{-----(B)}$$

The number of expected customers for group GSM will be $n^* S_1^*$ and for group AMPS, $n^* S_2^*$ assuming both groups to have identical cost and connection price structures.

For simplicity let $n = n^*$

Let

a_1 : The fixed costs exclusive of advertisement,

a_2 : The service cost per connection,

a_3 : The connection price and

a_4 : The proceeds (revenue) per connection

Then the expected profit for GSM group is P_{GSM} given by

$$P_{GSM} = a_3 n (S_1^* - S_1) - a_1 - a_2 n S_1^* - x + n S_1^* a_4 \quad \text{-----(1)}$$

And for AMPS group

$$P_{AMPS} = a_3 n (S_2^* - S_2) - a_1 - a_2 n S_2^* - y + n S_2^* a_4 \quad \text{-----(2)}$$

Let

n_1 : Number of current GSM users

n_2 : Number of current AMPS users

n_1^* : Number of expected GSM users in next quarter

n_2^* : Number of expected AMPS users in next quarter

$$S_1 = \frac{n_1}{n}, \quad S_2 = \frac{n_2}{n} \quad \text{and} \quad S_1^* = \frac{n_1^*}{n}, \quad S_2^* = \frac{n_2^*}{n}$$

Then

$$P_{GSM} = a_3(n_1^* - n_1) - a_1 - a_2 n_1^* - x + a_4 n_1^* \text{ -----(3)}$$

$$P_{AMPS} = a_3(n_2^* - n_2) - a_1 - a_2 n_2^* - y + a_4 n_2^* \text{ -----(4)}$$

Let $B = (a_3 - a_2 + a_4)$ then (3) and (4) can be written as

$$P_{GSM} = Bn_1 + B \frac{n_1 n_2}{n} \frac{(x - y)}{(x + y)} - a_3 n_1 - a_1 - x$$

$$P_{AMPS} = Bn_2 + B \frac{n_1 n_2}{n} \frac{(y - x)}{(y + x)} - a_3 n_2 - a_1 - y$$

Let $C = (B - a_3)$ then

$$P_{GSM} = Cn_1 + B \frac{n_1 n_2}{n} \frac{(x - y)}{(x + y)} - a_1 - x \text{ ----- (5)}$$

$$P_{AMPS} = Cn_2 + B \frac{n_1 n_2}{n} \frac{(y - x)}{(y + x)} - a_1 - y \text{ ----- (6)}$$

To theoretically determine exact saddle point, we will consider it as a two competitor game in which objective of GSM group is to maximize P_{GSM} and objective of AMPS group is to maximize P_{AMPS} . For this purpose we use elementary calculus to seek the optimal strategies.

$$(5) \Rightarrow \frac{\partial P_{GSM}}{\partial x} = \frac{2Bn_1 n_2 y}{n(x + y)^2} - 1 = 0$$

$$\Rightarrow x = \left(\frac{2Bn_1 n_2 y}{n} \right)^{\frac{1}{2}} - y \text{ ----- (7)}$$

Equation (7) describes the optimal spending by GSM group for any choice of y . substituting this value of x in (6), we get,

$$P_{AMPS} = Cn_2 - B \frac{n_1 n_2}{n} + \left(\frac{2Bn_1 n_2 y}{n} \right)^{\frac{1}{2}} - a_1 - y \text{ ----- (8)}$$

[Similarly, the optimal spending for AMPS group for any choice of x, we get

$$P_{GSM} = Cn_1 - B \frac{n_1 n_2}{n} + \left(\frac{2Bn_1 n_2 x}{n} \right)^{\frac{1}{2}} - a_1 - x \text{ ----- (9)}$$

Now we maximize P_{AMPS} (8) by solving

$$\frac{\partial P_{AMPS}}{\partial y} = \frac{(Bn_1 n_2 / n)^{\frac{1}{2}}}{(2y)^{\frac{1}{2}}} - 1 = 0$$

$$\Rightarrow y = \frac{Bn_1 n_2}{2n} \text{ Substituting in (7), we get}$$

$$x = \frac{Bn_1 n_2}{2n} \text{ as well.}$$

Thus this point $x = \frac{Bn_1 n_2}{2n}$, $y = \frac{Bn_1 n_2}{2n}$ is a true saddle point solution.

Application of model

As we have obtained saddle point for optimal spending of GSM and AMPS group, if $a_1= 300$, $a_2=500$, $a_3=500$, $a_4=2000$, $n=1000$, $n_1=550$ and $n_2=450$, we have,
 $x =247500$, $y =247500$

We consider above values for calculating profit, using (8) & (9) we get,

$$P_{GSM} = 577200 \text{ \& } P_{AMPS} = 427200$$

We can also observe the above saddle point through the graphs of equations (8) & (9) (See Fig. (a) & (b)).

Conclusion

The present model formulates a basic competitive condition in a market in which demand is fully rigid and the market has only two stake holders. To determine exact saddle point, we have considered it as a two competitors game applying elementary calculus to seek the

optimal strategy. An application of the model is demonstrated through a saddle point implying thereby that any other strategy would result in financial losses. The model can be suitably modified to incorporate more than two competitors.

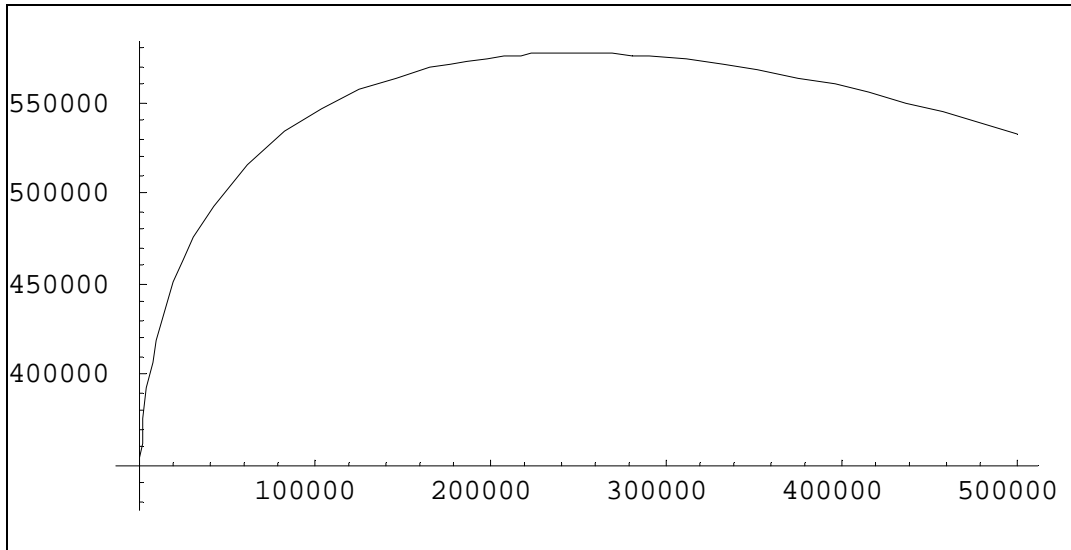


Figure: (a) Profit according to Expenditure for GSM Group

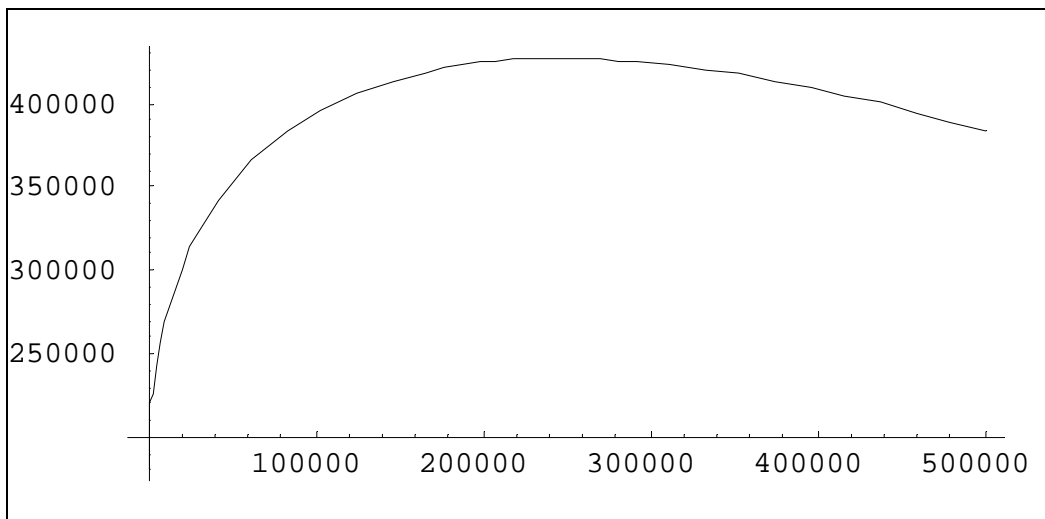


Figure: (b) Profit according to Expenditure for AMPS Group

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Bioaccumulation of chromium in various tissues of *Labeo rohita*

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Abstract

The bioaccumulation of chromium was studied in various tissues of *Labeo rohita* including kidney, muscle, gills and liver. The order of accumulation in these tissues was as follows kidney > gills > liver > muscle. There was however found decrease in tissue chromium level after few days of cessation of exposure.

Keywords: Chromium, *Labeo rohita*, bioaccumulation.

Introduction

Due to unplanned and indiscriminate waste disposal, both terrestrial and aquatic ecosystems are threatened by heavy metal contamination. Bioaccumulation of these metals adversely affects many tissues, disturbs metabolism and hampers growth and development. (Akram, *et.al.*, 1999). Heavy metals have longer biological half life that's why they accumulate. If the results of experimental research demonstrated on role of chemical agents in disease outbreak are taken into account, it becomes clear that a significant fraction of losses attributed to infections and invasive diseases is also due to contamination except that the effect is indirect. (Isayeva and Kozinenko, 1992). Chromium is an environmental contaminant that holds an important position in toxicological literature. (Senft and Kohout, 1996). Oxidation state of chromium as well as its concentration in medium is important in determining its toxicity. Hexavalent chromium is found more toxic than trivalent chromium. (Dirilgn and Doan, 2002). The heavy metals present the phenomenon of biomagnification and aquatic organisms can accumulate heavy metals up to levels 100,000 times greater than those present in water in which they live. (Abate, *et.al.*, 2003). These metals can cause death and sub-lethal effects on fishes in a variety of

ways. Many metallic compounds or ions accumulate in body tissues especially liver, kidney, gills, heart, spleen, bone and muscles. (Post, 1987). In this experimental work the accumulation of chromium in various tissues of farmed fish *Labeo rohita* is checked.

Materials and methods

The fish, *Labeo rohita* was procured from a local hatchery and the experiment was conducted in the experimental aquaria of zoology department, GCU Lahore. Hexavalent chromium was used in the form of potassium dichromate. The chromium was estimated in the following tissues of fish: liver, kidney, spleen, gills, and muscles. The chromium concentration was estimated by using Atomic Absorption Spectrometry. For this purpose the ash of each tissue was made separately in muffle furnace at 550°C temperature. One gram of the ash was taken and dissolved in 15 ml of HCl (6N). It was then digested in the flask until the volume remained 2 ml. The volume was then raised to 50 ml with deionized water. The samples were then filtered with 0.45 micron Millipore filter paper with help of micro filtration vacuum pump. The sample was then ready for chromium estimation on atomic absorption spectrometer (SOLAAR, 969, Thermo Elemental, U. K.). The data was analyzed

by using ANOVA (Analysis of Variance) and L.S.D. (least significant difference) (Sokal and Rolfs, 1981). The probability less than 0.05 ($P < 0.05$) were considered as significant. An asterisk represents the significant values in tables. The standard error of mean is represented by S. D.

Results

Chromium accumulation was checked in different tissues like kidney, liver, gills and muscle.

i- kidney

There was no chromium present in group A as it received no toxicant. In group B which received two daily exposures of chromium the amount of chromium accumulated was $0.051 \pm 0.00021 \mu\text{g}/\text{mg}$ of tissue. After two weeks this amount became $0.042 \pm 0.00012 \mu\text{g}/\text{mg}$ of tissue. After four and six weeks this amount further decreased to $0.026 \pm 0.00017 \mu\text{g}/\text{mg}$ and $0.0148 \pm 0.00015 \mu\text{g}/\text{mg}$ of tissue respectively, and after 8 weeks the amount remained was $0.011 \pm 0.00025 \mu\text{g}/\text{mg}$ of tissue (Table 1).

ii- Liver

In group A there was no chromium accumulation. Group B was exposed to two daily exposures of 12mg/lit. of chromium. The chromium estimated in the liver of this group was $0.032 \pm 0.00012 \text{ ppm}/\text{mg}$ tissue which later on after two, four, six and eight weeks became $0.0228 \pm 0.00008 \text{ ppm}/\text{mg}$, $0.018 \pm 0.0004 \text{ ppm}/\text{mg}$, $0.011 \pm 0.00025 \text{ ppm}/\text{mg}$ and $0.0068 \pm 0.00015 \text{ ppm}/\text{mg}$ of tissue respectively. (Table 2).

iii- Gills

Gills had no chromium accumulation in groups A. However in group B which received two daily exposures of toxicant there was $0.035 \pm 0.00028 \text{ ppm}/\text{mg}$ of tissue of chromium present. This amount

after two and four weeks became $0.0232 \pm 0.00008 \text{ ppm}/\text{mg}$ and $0.018 \pm 0.00013 \text{ ppm}/\text{mg}$ of tissue. After six and eight weeks chromium further reduced to $0.007 \pm 0.00018 \text{ ppm}/\text{mg}$ and $0.0018 \pm 0.00008 \text{ ppm}/\text{mg}$ respectively of gill tissue. (Table 3).

iv- Muscle

In muscle tissue, there was no chromium in group A. In the group B which was bare to two daily exposures of 12mg/lit. of toxicant showed $0.0282 \pm 0.00019 \text{ ppm}/\text{mg}$ tissue of chromium in muscle. After two, four, six and eight weeks this amount was reduced to $0.012 \pm 0.00025 \text{ ppm}/\text{mg}$, $0.009 \pm 0.00051 \text{ ppm}/\text{mg}$ and $0.0048 \pm 0.00049 \text{ ppm}/\text{mg}$ and $0.0024 \pm 0.00016 \text{ ppm}/\text{mg}$ tissue respectively. (Table 4).

Bioaccumulation of chromium in various **Discussion**

The chromium accumulation in tissues was in following order kidney > gills > liver > muscle. The amount of chromium accumulated in these organs decreased with passage of time. The increased accumulation of chromium in kidney might be due to diffusion process or it may have released the functional group in enzymes of kidney, as heavy metals are known to replace SH, amino, imino, carboxyl and phosphoryl groups in enzymes (Misra and Mani, (1992). Chromium may have come to the kidney from other parts to be excreted. With passage of time its accumulation decreased probably due to excretion of chromium by kidney. In gills chromium could have been accumulated directly by diffusion from surrounding water or it might have come from circulation. The decrease in chromium level may be due to the non-specific immune response present in gills. In the gills chromium might have been phagocytosed resulting in decreased values. Liver is the major detoxifying organ. Initially the chromium gets accumulated in it probably in the proteins

having bound to the enzymes. The diffusion of Cr in hepatocytes may also have contributed in its accumulation in organ. But as liver is a detoxifying organ so the metal concentration decreased with time. The dilution factor also may have contributed in decreased chromium. The chromium concentration in muscles was comparatively less than other organs. It is known that chromium is accumulated in aquatic species by passive diffusion (EPA US, 1978), and as muscles were in direct contact to skin so chromium might have diffused there. The decrease can be due to the reason that liver and components of immune system have not allowed the metal to reach muscles. The similar accumulation of chromium was reported

by Hernandez, *et. al.*, (1990) in fish. Gbem, *et. al.*, (2001) showed concentration and accumulation of chromium in liver, gills, gut and muscle of fresh water *Clarias gariepinus*. In *Labeo umbratus*, Coetzee (2002) found the chromium accumulation in liver, gills, skin and muscle. Similar bioaccumulation results are reported by different authors like Sriwastwa, *et. al.*, (1987) Elwood, *et. al.*, (1980), Deb and Santra (1997) and Abete, *et. al.*, (2003); Jafriet *et. Al.*, (1999) and Jafri *et al.*, (2003) in different fish species.

Table 1: Chromium accumulation in kidney of *Labeo rohita* after chromium exposure followed by antigen administration..

GR OUP	chromium accumulation (µg/mg TISSUE)					
	Toxi cant	0 day	2 weeks	4 weeks	6 weeks	8 weeks
A	-	0.000 ± 0.00	0.000 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B	+	0.051 ± 0.00021	*0.042 ± 0.00012	*0.026 ± 0.00017	*0.0148 ± 0.00015	*0.011 ± 0.00025

* P < 0.05

Data expressed as Mean ± S.D.

Table 2: Chromium accumulation in liver of *Labeo rohita* after chromium exposure followed by antigen administration.

GR OUP	chromium accumulation (µg/mg TISSUE)					
	Toxi cant	0 day	2 weeks	4 weeks	6 weeks	8 weeks
A	-	0.000 ± 0.00	0.000 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B	+	0.032 ± 0.00012	*0.021 ± 0.00028	*0.018 ± 0.0004	*0.011 ± 0.00025	*0.0068 ± 0.00051

* P < 0.05

Data expressed as Mean ± S.D.

Table 3: Chromium accumulation in gills of *Labeo rohita* after chromium exposure followed by antigen administration.

GR OUP	chromium accumulation ($\mu\text{g}/\text{mg}$ TISSUE)					
	Toxic ant	0 day	2 weeks	4 weeks	6 weeks	8 weeks
A	-	0.000 \pm 0.00	0.000 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
B	+	0.035 \pm 0.00028	*0.0232 \pm 0.00008	*0.018 \pm 0.00013	*0.007 \pm 0.00018	*0.0018 \pm 0.00008

*P < 0.05

Data expressed as Mean \pm S.D.**Table 4: Chromium accumulation in muscle of *Labeo rohita* after chromium exposure followed by antigen administration..**

GR OUP	chromium accumulation ($\mu\text{g}/\text{mg}$ TISSUE)					
	Toxic ant	0 day	2 weeks	4 weeks	6 weeks	8 weeks
A	-	0.000 \pm 0.00	0.000 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
B	+	0.0282 \pm 0.00019	*0.012 \pm 0.00025	*0.009 \pm 0.00051	*0.0048 \pm 0.00019	*0.0024 \pm 0.00016

*P < 0.05

Data expressed as Mean \pm S.D.

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Four new Monogenean and a Caryophyllid Cestode Parasites from Indigenous Catfishes of Bangladesh.

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Abstract

Investigation was conducted on helminth infestation in three species of indigenous catfishes namely *Ompok pabda*, *Clupisoma garua* and *Eutropiichthys vacha* from different water bodies of Mymensingh, Netrakona, Habiganj and Sunamgonj districts from June, 2003 to May 2004. Among a good number of helminth parasites collected from these fishes five species of monogenetic trematodes four of which described here are new species and a caryophyllid cestode also as new after critical morphological and taxonomical study. The identified monogeneans were *Silurodiscoides sudhakari* (Gussev, 1976), *Eutropiichthys vacha*; *Silurodiscoides, eutropiichthys* n.sp. from *Eutropiichthys vacha* and *Neosprostonia sunamgonji* n.sp. from *Clupisoma garua* and *Eutropiichthys vacha*. A single caryophyllid *Lytocestoides pabai* n.sp. was recovered from *Ompok pabda*.

Keywords: Monogeneans, Cestode, Parasites, Freshwater fish, Bangladesh

Introduction

Studies on helminth parasites of indigenous catfishes in Bangladesh are fragmentary. Though a number of helminthes are reported from catfishes, information on monogeneans is particularly limited. Most of the works were concentrated on walking catfish (Ahmed and Sanaullah, 1977; Rashid *et al.*, 1984; Ahmed *et al.*, 1985 and Chandra *et al.*, 1997). However, basic study on monogenean and caryophyllids have been done from different freshwater catfishes in Bangladesh, (Chandra and Khatun, 1993; Chandra and Yasmin, 2003; Begum and Chandra, 2003; Chandra and Banerjee, 1992; Hafizuddin and Shahabuddin 1996; Banerjee, and Jannat 2002). The other important related works in this region (Rizvi, 1971, Kulkarni, 1969, Lim, 1986, Tripathi, 1957, Jain, 1959 and Hafeezullah, 1993). Present investigation was initiated with a view to record the helminth infestation of indigenous catfish of freshwater bodies as a part of a project work funded by the

Bangladesh Agricultural University
Research system.

Material and methods

Samples of indigenous catfishes *Clupisoma garua*, *Eutropiichthys vacha* and *Ompok pabda* were manually collected from different areas of Bangladesh such as Mymensingh, Netrakona, Habiganj and Sunamgonj districts, a total 133 host fishes were examined. Both external and internal examinations were made for the collection of parasites. For external observation body slime and gills were examined.

Gills were dissected out from the bronchial cavity and placed in petridish containing distilled water and observed under dissecting microscope. The gills were gently scrapped to dislodge the live monogeneans from the gill filaments with the help of a bent needle and forceps. The monogeneans were picked up by a micropipette with a small drop of water on a glass slide and covered with cover

slip, sealed with 'sialant' to prevent them moving. After few minutes it was fixed with ammonium picrate. For internal examination the host fishes were dissected and opened along mid-ventral line. Each internal organ like liver, gall bladder, parts of alimentary tract were carefully opened separately by

0.007-0.011x 0.002 - 0.004mm; dorsal bar in the form of slightly curved chitinoid stick with widened round end, its size 0.004 -0.005 x 0.022-0.034 mm; ventral anchors with small roots and smoothly recurved point, their total length 0.026-0.029 mm; length of main part about 0.022 mm; of inner root

Results

Silurodiscoides sudhakari (Gussev, 1976) (Fig.1)

Host	: <i>Eutropiichthys vacha</i>
Localities	: Mymensingh, Netrakona (Mohongonj) and Sunamgonj
Site of infestation	: Gill filaments
No. of parasites measured	: 5
Prevalence (%)	: 30.23

longitudinal incision and observed for presence of any metazoan parasite under microscope. The cestode worm was fixed in AFA, stained in alum carmine and mounted in Canada balsam. Parasites were drawn with the help of a Camera lucida.

Description

Small to moderate-sized worms, length 0.970mm 0.870-1.150; width 0.130mm 0.090-0.180; two pairs of eyespots scattered as pigment granule in some specimens; pharynx nearer to the head spherical; 0.074mm x 0.062mm.

The opisthaptor has two pairs of anchors, a dorsal and a ventral pair. Dorsal anchors with powerful sabre-like point and small wing. Their total length 0.046 mm - 0.042-0.048, length of main part 0.033-0.036 mm, of inner root, 0.014 - 0.017mm, point 0.019-0.021mm. The patches of dorsal anchors were widened at one termination, and narrowed towards the other, their size

0.002-0.004mm; of point 0.012-0.014mm; ventral connective bar-shaped, size of its every S-shaped half 0.0018-0.0029 x 0.029-0.031mm; hooks of larval type with protruding 'heel' of hooklet; their total length 0.013-0.021mm.

Copulatory complex consists of a spiral, coil-shaped tube with widened initial part almost cylindrical on its terminal end and a curved getter-shaped accessory piece. Its length along curve 0.027-0.029 mm; initial part 0.03-0.0017 mm; length of accessory piece 0.032-0.037 mm; width 0.009-0.019mm; length of accessory piece 0.032-0.037 mm; width 0.009-0.019 mm; vaginal armament with a cylindrical tube bending into a bubble-like widening at one end; length of vaginal tube 0.011-0.011 at one end; length of vaginal tube 0.011-0.012 mm in width.

Discussion

The specimen resembles *Silurodiscoides sudhakari* (Gussev, 1976) collected from the gill filaments of *Wallago attu* from

Bhavanisagar reservoir, India; in all of its morphology and main identifying characters but minor differences found in some measurements and structure of dorsal bar which may be an individual variation due to host differences. Therefore it has been identified as *Silurodiscoide sudhakari* (Gussev, 1976) reported from Bangladesh water and from the new host.

Copulatory complex larger, present at the anterior half of the body. It consists of an elongated tube and an accessory piece. Tube coiled; length about 0.250mm, diameter of anterior widened part 0.008 mm, middle 0.001mm and distal widened part 0.005mm. accessory piece claw like peculiar shaped, its length 0.058mm; vaginal armament with a small semi-curved attached with a long zigzag coiled narrow tube.

***Silurodiscoides eutropiichthys* n.sp. (Fig.2)**

Host	: <i>Eutropiichthys vacha</i>
Localities	: Sunamgonj
Site of infestation	: Gill filaments
No. of parasites measure	: 3
Prevalence%	: 16.27

Description

The fluke is elongate in size, length 1.850-2.000mm, width 0.170-0.190mm. Eye goblets scattered along anterior end of body as individual granules. Mouth bears muscular pharynx, which is 0.120mm diameter. Opisthaptor not constrict off from body proper but with two pairs of dissimilar anchors. Dorsal anchors larger, have ridge like structure at the base, total length 0.048-0.052mm, the main part 0.041mm, length of inner root 0.008mm, triangular elongate patches 0.21mm x 0.008mm in size, with sharp point, 0.022mm. Dorsal connective bar curved with widened middle, 0.009 x 0.047mm. Ventral anchors, 0.025-0.28mm, with well developed roots, 0.003mm and curved point, 0.014mm. Ventral bar flexible} – shape, half of its size 0.006 x 0.035mm. Marginal hooks with protruding ‘heel’ of hooklet. Their length 0.013 – 0.015mm, handle 0.008 mm and point 0.005 mm.

Discussion

The species collected from *Eutropiichthys vacha* coincides with the basic generic characters of the genus *Silurodiscoides* but differs morphologically from other reported species of the genus. The following species are record as catfishes under the genus: *S. inicus*, Kulkarni (1969), *S. sunhakari* Gussev (1976), *S. octotylus* Kulkarni (1969), *S. devarajii* Gussev (1976), *S. malabaricus* Gussev (1976), *S. vaginalis* Gussev (1976), *S. aori* Rizvi (1971), *S. pusillus* Gussev (1976), *S. purvalus* Gussev (1976), *S. microhaptorus* Lim (1986). As the present form does not coincide with the basic morphological feature of any known species it warrants erecting a new species for this form and the name *Silurodiscoides eutropiichthys* n. sp. is proposed after the name of the host genus for its acceptance.

***Bychowskyella vachai* n.sp. (Fig.3)**

Host	: <i>Eutropiichthys vacha</i>
Localities	: Mymensingh, Mohongonj, Surma river at Sunamgonj
Site of infestation	: Gill filaments
No. of parasites measure	: 5
Prevalence%	: 20.93

Description

The fluke with medium body, length 0.888mm (0.747-0.971); breadth 0.133mm (0.099-0.166); halter broader than the body 0.158-0.174 x 0.141-0.191 mm in size; four pairs of head organs; Eyepots absent only separate pigment granules dispersed in the anterior part of body; pharynx ovoidal, 0.034-0.048 x 0.041-0.058 mm; intestinal crura extends down to the posterior quarter of the body.

Two pairs of unequal anchors of which dorsal anchor is 0.058mm (0.056-0.059); its sharp point 0.009-0.011mm in length; a single dorsal bar lip-shaped widened in the middle with articulate knob measuring 0.013 mm (0.011-0.017) x 0.056mm (0.053-0.058). Each of the dorsal anchors with an accessory piece at its base, curved and tapering size 0.048 x 0.008mm; ventral anchors smaller than dorsal one have wings not reaching to the point total length 0.030- 0.036mm; length of main part 0.026-0.033mm; inner root 0.004-0.005mm; outer root 0.003-0.004mm; point 0.014-0.016mm; a spiny ear-like accessory piece attached at the base of ventral anchor, its size 0.003-0.004 x 0.002-0.003mm; ventral paired bars meet in the median line size 0.008-0.010 x 0.049-0.055mm.

The ventral cuticular plate or 'onchium' is Y-shaped 0.021mm (0.019-0.022) x 0.0019mm (0.017-0.021); seven pairs of marginal hooklets of these three pairs are

larger 0.031-0.042mm; one pair near the onchium, one pair behind it, and the third pair near dorsal anchors. Four pairs of small marginal hooklets present near the margin; size about 0.014 -0.017mm.

Copulatory complex consists of a smooth curve tube and an accessory piece. The length of tube along curve 0.053mm (0.052-0.054); diameter of its widened initial part 0.012-0.013mm; middle 0.004-0.007mm and posterior 0.001-0.003mm; accessory piece looks like a thin tape going from initial part of tube and forming 2/3 horned widening part at its end its length 0.054-0.059mm. Vaginal armament not observed.

Discussion

The present specimens coincide with the generic characters of the genus *Bychowskyella* Ahneriwm (1952) in the structure of dorsal and ventral anchors, patches, copulatory complex, presence of onchium and number of hooks; the best known species of the genus are, type species *B. pseudobagri* Achmerow, (1952) recorded from *Parasilurus asotus* and *B. tchangi* Gussev, (1976) describe from *Clarias batrachus* in India. Tripathi (1957) described several species after erecting a new genus *Silonditrema* but Jain (1959) synonymized *Silonditrema* as *Bychowskyella* later accepted by Gussev (1976). They state that presence of onchium in some species and peculiar ear-shaped processes on the shaft of ventral

anchors do not give any base for separating it into different genera.

Gussev (1976) also stated that despite great similarities the presence of onchium in *B. garui* and its absence in *B. indica* also differs in the shape of vaginal armament, they should be considered as independent species. Here different hosts are important characters.

anchors with sharp point, indistinct roots, comparatively broadened at the base, total length 0.044mm (0.042-0.046); length of main part 0.037-0.042mm, length of point 0.018mm (0.0166-0.021); patches short, triangular, length 0.018mm (0.016-0.020); width 0.008mm (0.007-0.009); dorsal connective bar widened at the middle, where there are two articulate

***Bychowskyella vachai* n.sp. (Fig.4)**

Host	: <i>Clupisom garua</i> and <i>Eutropiichthys vacha</i>
Localities	: Mymensingh, Habigonj and Sunamgonj
Site of infestation	: Gill filaments
No. of parasites measure	: 5
Prevalence%	: 20.93 – <i>C. garua</i> 16.27 – <i>E. vacha</i>

However, the present specimen though resembles *B. pseudobagri* but differs in the presence of onchium and process on the shaft of ventral anchors also, to an extent. On the basis of this ground present specimen collected from *Eutropiichthys vacha* is erected as an independent species and the name *Bychowskyella vachai* n.sp. is proposed.

Description

Elongated body 2.797mm (2.130-3.150) long; 0.380 mm (0.270-0.400) wide. Two pairs of eyespots; posterior two eyespots dispersed as pigment granules. Pharynx spherical to ovoid at the anterior part of body its size is 0.137 x 0.145mm. Head organs located at anterior region.

Haptor is armed with seven pairs of hooks and two pairs of anchors; the ventral pair nearly half of the dorsal pair; dorsal

knobs, its size 0.017-0.022 x 0.048-0.052mm; Ventral anchors with total length 0.029-0.030mm, accessory piece on the base of ventral bar 0.004-0.005mm length of point 0.017-0.018mm; ventral connective bar paired, meet at the midline, articulate at widened end, with knob of 0.004mm, length of each half 0.008-0.010mm, width 0.041-0.046mm.

Three pairs of hooks larval type; their length 0.015-0.017mm, diameter of handle of these hooks about 0.002mm; hooks of two pairs with long widened handle and thickened pivot of handle, their total length 0.042-0.024mm, with handle 0.005-0.007mm; one pair of hooks near the base of dorsal anchors 0.029-0.030mm long, diameter of handle 0.003mm; one pair of hooks near the ventral anchors, length 0.018-0.021mm, and diameter of handles 0.002mm.

Copulatory organ consists of tube and accessory piece. Tube smoothly curved with widened initial part almost cylindrical on its rest part. Its length along curve 0.052-0.058mm, diameter of initial part 0.009-0.012mm, of medial part 0.004-0.005mm. Accessory piece look like a thin tape whose lateral lines are rough, going from the initial part of tube and embraces the tube near about its end; its length 0.048-0.057mm. Vaginal armament was not found.

(0.020-0.0260); each consists of a stout rounded base and a stout shaft. The base has a small lateral projection, with no differentiation of superficial and deep root. The bar between the dorsal anchors is smaller and lip-shaped with a wide aperture in the middle, its length 0.016mm (0.010-0.017) and width 0.069mm (0.058-0.079); at the root of each anchor of the dorsal pair an

Neosprostonia sunamgonji n.sp. (Fig.5)

Host	: <i>Clupisoma garua</i> and <i>Eutropiichthys vacha</i>
Localities	: Mymensingh, Habigonj and Sunamgonj and Surma river
Site of infestation	: Gill filaments
No. of parasites measure	: 5
Prevalence%	: 32.70-C.garuai 34.88 – E, vacha

Discussion

The present specimen collected from *Eutropiichthys vacha* and *Clupisoma garua* belongs to be genus *Bychowskyella* Achmerow, 1952. The present specimens seem only nearer to *Bychowskyella tchangi* (Gussev, 1976) general morphology but differs in the structures of chitinoid haptor armature like hooks bar and anchors and their measurement of different parts so it has been considered as a new species and the name *Bychowskyella garuai* is proposed.

Description

Body of the parasite is elongated, length 1.20mm (0.91-1.59), breadth 0.18mm (0.13-0.21) slightly broadening in the ovarian region; haptor (0.192mm x 0.178mm) completely demarcated with two pairs of anchors; dorsal pair of anchors is long, 0.073mm (0.071-0.075) and the point more or less straight

0.022mm accessory bar is attached. The accessory bar is thicker at the outer end; tapering on the inner side and strongly curved, about 0.059 x 0.009mm; anterior to this a pentagonal chitinous conspicuous onchium (0.025-0.027mm) is present on the ventral side.

Ventral pair of anchors is nearly three-quarters of the dorsal pair in size, length 0.065mm (0.060-0.074), having a spur on the outer side near the base of the shaft; anterior and internal to the curvature of the anchor point. The bars attached with the ventral pair are thinner and longer 0.011 (0.008-0.012) x 0.077 (0.064-0.086mm) joining in the middle.

Each hook consists of an elongated base, and insignificant shaft and a small crochet-shape portion. Four rod like hooks are present near the plate, size 0.038mm (0.035-0.044); three pairs of small curve hooklets (0.021mm) present along the margin of the haptor; two pairs

of sickle-shaped hooks, 0.036-0.047mm, located near the base of dorsal anchor.

Head provided with four pairs of head organs and two pairs of eyespots; in some specimen eye goblets scattered along anterior end of body as individual granules. pharynx spherical, 0.04-0.06mm; copulatory complex very stout consisting of very long cork-screw-like cirrus; 0.048mm x 0.043mm, an elongated accessory piece and a coiled cirrhal thread. The cirrus and the accessory piece are firmly articulated at the base; is thick-walled hollow tube having 3 or 4 spiral turns around the accessory piece; length 0.192-0.402mm; the accessory piece lies parallel to the cirrus and is 0.014-0.18 mm long. The vagina has a short funnel shaped mouth and a looped vaginal tube. The single egg 0.108 x 0.061 mm is oval with a hook like projection.

Discussion

The genus *Neosprostonia* was erected by Jain (1959) for a new monogenean collected from the gill filaments of *Eutropiichthys vacha* (Ham.), here to the known species of the genus *Neosprostonia* Jain, 1959 are *N. indica*, *N. gomia*, *N. asiatica* and *N. wallagonia*. The hosts for the later two worms, *Callichorous pabda* (Ham.) and *Wallagonia attu* (Sch). Agarwal and Singh (1982) are reported *N. garuai* for the first time from *Clupisoma garua*. The present specimens collected from *Clupisoma garua* resembles *N. gomia* in many characters

and measurements but differs in the presence of egg and other morphological structure of copulatory complex which somewhat coincides with the *N. indica* (Table 1). These distinguishing armatures warrant erecting a new species for this specimen, which can be titled as *Neosprostonia sunamgonji* n.sp. after the name of the locality of collection of the host fish.

Table 1: Comparison of measurements and characteristics of *Neosprostonia gomtia*, *Neosprostonia indica* with the present species

Morphological Characteristics	<i>Neosprostonia Sunamgonji</i> n.sp.	<i>Neosprostonia gomtia</i>	<i>Neosprostonia inidica</i>
body length	0.910-1.590	0.70-0.820	0.550-0.690
Breath	0.130-0.210	0.100-0.120	0.038-0.080
Position and size of pharynx	Nearer to the head; 0.040-0.060	Nearer to the head; 0.030 x 0.035	Comparatively far from the head; 0.025
Eyespot	Scattered as pigment granules	Two pairs	Two pairs; one pair scattered.
Dorsal anchor shape an size Ventral anchor length and shape	Elongate 0.071-0.075, points more or less straight. About three quarters of the dorsal anchor, 0.060-0.074.	Length 0.07-0.076mm, Consists of a fine recurved point. Wing present. Length 0.037-0.042	Length 0.062-0.075 No wing length 0.048-0.057.
Size and shape of hooks	Seven pair hooks are same in shape but differ in size; 2 pair larger hooks 0.035-0.044; three pair smaller marginal hooks 0.021 and two pair sickle-shaped hooks 0.036-0.047.	Seven hooks similar in shape, their dimension ranges 0.009-0.044.	Seven pair hooks;
Size and shape of dorsal bar	Lip shaped, with wide aperture in the middle; 0.016 x 0.069; Accessory bar strongly curved 0.059 x 0.009;	Straight has a large aperture in the middle 0.062 x 0.015; Accessory bar 0.043-0.045 in length.	Dimension ranges 0.011-0.037
Size and shape of ventral bar	Thin and elongate 0.011 x0.077	Straight 0.11-0.125 long	Straight has a large aperture in the midle 0.056 x 0.013; Accessory bar length 0.032-0.036; stout, transverse shaft.
Onchium	Pantagonal 0.025-0.027	Leaf like, 0.024-0.027	Absent
Copulatory organ	Consists of long cork screw-like cirrus, 0.048 x 0.043, coiled cirrhal thread.	Cirrus stout, thick walled, 0.08-0.084 long	Cirrus stout thick walled 0.125-0.165.

***Lytocestoies pabdai* n.sp. (Fig.6)**

Host	: <i>Clupisoma garua</i> <i>Ompok pabda</i>
Localities	: Sunamgonj Habigonj
Site of infestation	: Intestine
No. of parasites measured	: 5
Prevalence%	: 25

Description

Body elongated, unsegmented, slightly tapering posteriorly. Length of body 3.03-4.77mm, with 0.81-0.96mm. Scolex reduced unspecialized. Neck absent testes follicular numerous (about 80-150), mularly distributed from the base of scolex to cirrus sac; size 0.21 x 0.18mm to 0.42 x 0.37mm; vitellaria extending throughout in cortical parenchyma, in double field. Postovarian vitellaria absent. Vitelline follicles, 38-57 regular in shape form a continuous layer surrounding testes.

Ovary bilobed butterfly-shaped in the posterior region of body length 0.50-0.65mm with 0.54 - 0.58mm lobes connected by narrow isthmus measuring about 0.07mm; uterine region comparatively short not extending anterior to cirrus sac; gonoducts separate. Intrauterine eggs numerous 0.021 x 0.020 mm to 0.023 x 0.022mm in size.

Remarks

The present specimen belongs to the order Caryophylliea as it has no segmentation in its body. No proper development of scolex at its anterior end. Several genera have been reported from this order in Bangladesh and India. The present genus *Lytocestoies* Baylis, (1928) reported H-shaped ovary, follicular testes, separate gonopore. Mackiewicz (1981) stated that the characters like reduced and widened scolex, the body tapering gradually

posteriorly right from anterior end testes extending to near anterior end of body; presence of postovarian follicles of vitellaria and butterfly shaped ovary suggests the genus *Breviscolex* Kulashovskaya (1962) in the family Capingentiae. But the present specimens have no postovarian vitelline follicles. But most of its characters resemble *Lytocestoies* and is therefore described under the genus *Lytocestoies*. A number of species of the genus *Lytocestoies auranabadensis*, *L. naldurgensis* *L. mackiewiezi* were synonymized with the genus *Breviscolex* and *L. fossilis* was synonymized with *Lytocestus* Cohn, (1908) Hafeezullah, 1993. Therefore only a single species *Lytocestoies pithiness* Shine and Desmukh, (1975) recorded from *Pseudeutropius taakree* of Godavari river is valid species of Indian subcontinent. The present specimen differs from *L. paithanensis* in the position of genital pore situated at the posterior half of the body and shorter and straightened uterus so it may be considered as a new species and *Lytocestoies pabdai* is proposed as its specific name.

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Fig. 1. *Siluroiscoies Suhakari* (Gussev, 1978)

A. Entire fluke B. Dorsal anchor C. Supporting bar (dorsal). D. Ventral anchor
E. Supporting bar (ventral) F. Copulatory complex G. Marginal hook

Fig. 2. *Siluroiscoies eutropiichthyes* n.sp.

A. Entire fluke B. dorsal anchor C. Supporting bar (dorsal) D. Ventral anchor
E. Supporting bar (ventral) F. Copulatory complex G. Marginal hook

Fig. 3. *Bychowskyella vachai* n. sp.

A. Entire fluke B. Dorsal anchor C. Supporting bar (dorsal) D. Ventral anchor
E. Supporting bar (ventral) F. Onchium G. Copulatory complex H. Marginal hooks

Fig 4. *Neosprostonia sunamgonji* n.sp.

A. Entire fluke B. Dorsal anchor C. Supporting bar (dorsal) D. Ventral anchor
E. Supporting bar (ventral) F. Copulatory complex G. Onchium H. Marginal hooks
I. Egg.

Fig 5. *Bychowskyella garuai* n. sp.

A. Entire fluke B. Dorsal anchor C. Supporting bar (dorsal) D. Ventral anchor
E. Supporting bar (ventral) F. Copulatory complex G. Marginal hooks .

Fig. 6 . *Lytocestoides pab dai* n.sp.

A. Entire tape worm

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Global solar radiation over Pakistan Comparison of measured and predicted data

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Abstract

The estimates of global solar radiation on horizontal surface at Karachi, Lahore, Multan, Peshawar and Quetta were calculated using Angstrom formula which correlates relative global solar irradiance $\overline{H}/\overline{H_0}$ to corresponding relative duration of bright sunshine $\overline{n}/\overline{N_d}$. The coefficient of this relationship were obtained by regression analysis using daily global radiation and sunshine data measured in these cities over a period of eighteen to twenty seven years and twenty seven to thirty four years respectively. The estimated values of global solar radiation \overline{H} were then compared with the measured values both by graphical and statistical methods based on calculation of Mean Bias Error (MBE), Root Mean Square Error (RMSE), Coefficient of Correlation (r) and Coefficient of Determination (r^2) and were found in good agreement. Thus the correlation of Angstrom is the best estimator for global solar radiation over Pakistan.

Keywords: Solar radiation, statistical evaluation.

Introduction

The design and estimation of the performance of all solar energy conversion system require the knowledge of solar radiation data. These data are not easily available for many countries. Many countries cannot afford the measurement equipment and techniques involved. Bright sunshine hours are measured at many locations around the while global radiations are measured at selected stations or locations only. To fill this gap various models have been developed to predict the amount of solar radiation available at any location using whatever weather data or parameters are available (1-4). These parameters include (i) the sunshine hours (5-8), (ii) the relative humidity and sunshine (9), (iii) the later two in addition to the mean temperature (10), (iv) the declination angle and the latitude (11-14), (v) the later two in addition to the sunshine duration (15-16), (vi) the number of rainy days, sunshine hours, latitude of location (17), (vii) the sunshine duration, relative humidity, maximum temperature, latitude, altitude and location (18), (viii) the total

precipitable water, turbidity and surface albedo (19).

Pakistan is a high insulation country. It receives about 1kW of solar energy for square metre of its landmass for 6-7 hours on the average per day. The number of sunshine hours amount almost to 3000-3300 per year. The weather is most favourable for the utilization of solar energy. The importance of present work stems from the fundamental need of knowledge of solar radiation data in the country.

Of the above mentioned models the most popular and established correlation is the modified form of Angstrom type (20)

$$\overline{H}/\overline{H_0} = ?_0 + ?_1 (\overline{n}/\overline{N_d}) \dots (1)$$

Where \overline{H} is the monthly mean daily global radiation falling on a horizontal surface at a particular location ($MJm^{-2} d^{-1}$) $\overline{H_0}$ is the monthly mean daily radiation on a horizontal surface in the absence of any atmosphere at a particular latitude ($MJm^{-2} d^{-1}$) n is the monthly mean daily number of hours of sunshine in a

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given month between sunrise and sunset (hr.day⁻¹); and α_0 and α_1 are climatologically determined regression coefficients, \bar{n}/N_d is often called the percentage possible sunshine. This relation is very simple and easy to handle. Furthermore it requires only a few input parameters which are either available from the local observatory or can readily be computed. In the present work equation (1) is used to determine α_0 and α_1 for five cities in Pakistan (Karachi, Lahore, Multan, Peshawar and Quetta). The geographical locations of the cities together with the duration of record used are shown in Table 1.

Estimated global radiation

The mean monthly daily global solar radiation, for each of the five cities, was calculated from equation (1) after obtaining the coefficients α_0 and α_1 for each city. In these calculations, the values of H_0 were calculated from (21) as

$$\bar{H}_0 = 24/p \text{ lsc} [1 + 0.033 \cos 360 \bar{n}/365] \times [\cos \alpha \cos d \sin w_s + 2 p/360 \sin \alpha \sin d \dots] \quad (2)$$

Where lsc is the solar constant (taken as 4.871 MJm⁻² hr⁻¹ in the present calculations), n is the day of the year given for each month (21), α is the latitude, d is the solar declination (Table-2) and w_s is the sunset hour angle given by the equation

Stations	Latitudes (N)		Longitudes(E)		Altitude Metre	Duration of Records	
	deg.	sec.	deg.	sec.		Sunshine Years	Radiation Years
Karachi	24	52	67	08	22.0	33	27
Lahore	31	33	74	20	214.0	34	18
Multan	30	12	71	26	123.0	28	27
Peshawar	34	00	71	31	569.7	34	21
Quetta	30	11	66	57	1799.0	27	27

$$w_s = \cos^{-1} (-\tan \alpha \tan d).$$

Table 1: Geographical location of stations and duration of records

Month	n for the i th day of the month	For the average day of the month		
		Day of the year		Declination (d)
		Date	n	Deg.
January	i	17	17	-20.92
February	31+ i	16	47	-12.95
March	59+ i	16	75	-2.42
April	90 + i	15	105	18.79
May	120 + i	15	135	23.09
June	151 + i	11	162	21.18
July	181 + i	17	198	13.45
August	212 + i	16	228	2.22
September	243 + i	15	258	-9.60
October	273 + i	15	288	-18.91
November	304 + i	14	318	-23.05
December	334 + i	10	344	

Table 2: Recommended average day for each month and value of n by months

The coefficients α_0 and α_1 were calculated from values of \bar{H}/\bar{H}_0 and \bar{n}/\bar{N}_d for each month of the year from the available data. The measured values of the monthly mean daily global radiation, \bar{H}_0 , were obtained from the measured daily values. The values of the monthly mean daily extra terrestrial radiation \bar{H}_0 were calculated from equation (2) as outlined previously. The measured monthly mean daily number of bright sunshine hours, \bar{n} and the monthly mean daily theoretical number of sunshine hours, \bar{N}_d were determined from their measured values. Tables 3-7 show results for the five cities.

In this way, the values of \bar{H}/\bar{H}_0 and \bar{n}/\bar{N}_d for each month may be determined. Accordingly, twelve equations (one for

each month) for each location may be written. Each equation is of form

$$Y = \alpha_0 + \alpha_1 x \dots\dots\dots(3)$$

Where $Y = \bar{H}/\bar{H}_0$ and $x = \bar{n}/\bar{N}_d$. The least square method was then used to calculate the coefficients α_0 and α_1 for the different locations

The following correlations were obtained:

$$\bar{H}/\bar{H}_0 = 0.345 + 0.369 (\bar{n}/\bar{N}_d), \text{ Karachi } \dots\dots (4)$$

$$\bar{H}/\bar{H}_0 = 0.385 + 0.243 (\bar{n}/\bar{N}_d), \text{ Lahore } \dots\dots (5)$$

$$\bar{H}/\bar{H}_0 = 0.422 + 0.253 (\bar{n}/\bar{N}_d), \text{ Multan } \dots\dots (6)$$

$$\bar{H}/\bar{H}_0 = 0.569 + 0.066 (\bar{n}/\bar{N}_d), \text{ Peshawar } \dots (7)$$

$$\bar{H}/\bar{H}_0 = 0.402 + 0.382 (\bar{n}/\bar{N}_d), \text{ Quetta } \dots\dots (8)$$

Months	$\bar{H}_0 (MJm^{-2} d^{-1})$	\bar{n}/\bar{N}_d	$\bar{H} (MJm^{-2} d^{-1})$		Error (%)
			Measured	Calculated	
January	23.986	0.8301	15.827	15.622	1.295
February	28.187	0.8165	17.962	18.217	-1.420
March	32.960	0.7550	21.019	20.554	2.212
April	37.076	0.7574	22.484	23.153	-2.975
May	39.292	0.7411	23.447	24.301	-3.642
June	39.941	0.5765	22.735	22.276	2.019
July	39.490	0.3628	19.218	18.911	1.597
August	37.783	0.3848	17.837	18.399	-3.151
September	34.338	0.6039	19.846	19.498	1.754
October	29.501	0.8121	19.344	19.018	1.685
November	24.921	0.8570	16.413	16.479	-0.402
December	22.726	0.8300	14.864	14.801	0.424

Table 3: Comparison between measured and calculated values of \bar{H} for Karachi

Months	$\bar{H}_0 (MJm^{-2} d^{-1})$	\bar{n}/\bar{N}_d	$\bar{H} (MJm^{-2} d^{-1})$		Error (%)
			Measured	Calculated	
January	20.131	0.6837	10.719	11.0835	-3.405
February	24.894	0.7160	13.942	13.8993	0.308
March	30.643	0.6688	18.213	16.7603	7.978
April	36.110	0.7226	20.893	20.2219	3.212
May	39.543	0.7346	22.819	22.2595	2.450
June	40.784	0.6539	22.317	22.1595	0.703
July	40.065	0.5524	20.558	20.7822	-1.089
August	37.332	0.5886	18.758	19.6925	-4.985
September	32.544	0.7256	18.255	18.2486	0.033
October	26.521	0.8319	15.115	15.5552	-2.911
November	21.215	0.8403	12.435	12.4864	-0.410
December	18.764	0.7329	10.216	10.5549	-3.318

Table 4: Comparison between measured and calculated values of \bar{H} for Lahore

Months	\overline{H}_0 (MJm ⁻² d ⁻¹)	$\overline{n}/\overline{N_d}$	\overline{H} (MJm ⁻² d ⁻¹)		Error (%)
			Measured	Calculated	
January	20.894	0.7128	12.687	12.5876	0.7803
February	25.556	0.7005	15.408	15.3162	0.5971
March	31.126	0.7005	18.758	18.6541	0.5544
April	36.335	0.7138	22.735	21.8983	3.6815
May	39.530	0.6976	24.201	23.6621	2.2272
June	40.654	0.6631	23.531	23.9807	-1.9124
July	39.988	0.6404	23.196	23.3586	-0.7027
August	37.456	0.6825	21.731	22.2778	-2.5171
September	32.928	0.7442	20.391	20.0978	1.4369
October	27.127	0.8076	16.748	16.9853	-1.4151
November	21.951	0.8197	13.859	13.8165	0.3031
December	19.544	0.7506	11.556	11.9604	-3.4960

Table 5: Comparison between measured and calculated values of \overline{H} for Multan

Months	\overline{H}_0 (MJm ⁻² d ⁻¹)	$\overline{n}/\overline{N_d}$	\overline{H} (MJm ⁻² d ⁻¹)		Error (%)
			Measured	Calculated	
January	18.648	0.6278	11.263	11.3799	-1.0388
February	23.583	0.6354	14.655	14.4032	1.7195
March	29.670	0.5417	18.297	17.9382	1.9621
April	35.628	0.6127	21.731	21.7065	0.1104
May	39.521	0.6841	25.122	24.2637	3.4135
June	40.990	0.7028	25.959	25.2160	2.8622
July	40.168	0.6429	23.447	24.5522	-4.7128
August	37.043	0.6598	21.354	22.6832	-6.2237
September	31.759	0.6905	19.386	19.5116	-0.6499
October	25.320	0.7724	15.869	15.6920	1.1154
November	19.778	0.7729	12.728	12.2580	3.6926
December	17.253	0.8604	10.468	10.7922	-3.0951

Table 6: Comparison between measured and calculated values of \overline{H} for Peshawar

Months	$\bar{H}_0 (MJm^{-2} d^{-1})$	\bar{n}/N_d	$\bar{H} (MJm^{-2} d^{-1})$		Error (%)
			Measured	Calculated	
January	20.894	0.6691	14.110	13.7358	2.6293
February	25.556	0.6930	16.581	17.0376	-2.7562
March	31.126	0.6495	20.349	20.1805	0.8256
April	36.335	0.7094	20.950	24.3899	-1.8372
May	39.530	0.8043	27.467	27.9690	-1.8276
June	40.654	0.8304	29.686	29.1700	1.7382
July	39.988	0.7590	26.881	27.6004	-2.6748
August	37.456	0.8485	26.420	27.1346	-2.7063
September	32.928	0.7974	24.201	23.2110	4.0907
October	27.127	0.8938	20.349	20.1218	1.1155
November	21.951	0.8649	16.162	16.0398	0.7549
December	19.544	0.7308	13.608	13.2789	2.4177

Table 7: Comparison between measured and calculated values of \bar{H} for Quetta

Results and discussion

The present results indicate that the coefficients ρ_0 and ρ_1 depend on location. Comparison between estimated and measured global radiations shows that the present equations (4-8) can be used to predict the monthly mean daily global radiation in the locations considered in this study.

The percentage errors between the calculated and measured values of the monthly mean daily global radiation \bar{H} were estimated for the five cities for the twelve months of the year. These errors are given in Tables 3-7. The minimum and maximum percent error for the five cities ranged as under.

Through the monthly average of the measured global radiation on a horizontal surface and the average monthly total hours of sunshine per day has been obtained for the period of 18 to 27 years and for the periods of 27 to 34 years respectively comparison of an individual calculated value against a measured or percent difference is inadequate to test the accuracy of a predictive model.

Figures 1-5 show the plot of the predicted values along with the measured values. It appears from the figures that a visual comparison of these results is also insufficient to test the accuracy of the predictive model.

Station	Minimum percent error	Maximum percent error
Karachi	-3.6420	2.2120
Lahore	-4.9850	7.9780
Multan	-3.4960	3.6815
Peshawar	-6.2237	3.6926
Quetta	-2.7562	4.0907

Figures 6-10 show a relationship between the predictive global solar radiation and measured global solar radiation. It appears from the graphs that there is fairly good agreement between the measured monthly values of global solar radiation and the predicted values obtained with the modified Angstrom Correlation.

To check further the accuracy of the predictive model a number of useful statistical tests based on calculation of Mean Bias Error (MBE), Root Mean Square Error (RMSE), Correlation Coefficient (CC or r) and Coefficient of Determination (r^2) are made. Results of these tests are listed in Table 8. From Table 8 it is evident that the MBE ranged between -0.0446 to $+0.0194$ which is very close to the ideal value i.e. zero, whereas the RMSE ranged between 0.3932 to 0.6361 which is not close to zero. The values of Correlation Coefficient ranged between 0.9884 to

0.9960 . The Coefficient of Determination ranged between 0.9770 to 0.9920 . The minimum and maximum for both the cases are very close to unity. Thus correlation of Angstrom in my opinion is the best estimator of global solar radiation.

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Table 8 also shows that the sum ($?_0 + ?_1$) which represents that clear day fraction of H_0 decreases systematically with the increase in Latitude except for Quetta where the sum ($?_0 + ?_1$) increases abruptly though the latitude lies between $24^{\circ}52'$ and $30^{\circ}12'$. The annual average of $\overline{n/N_d}$ also tends to show a similar variation with Latitudes.

Station	Latitude(N)		Annual Average		Regression coefficients			MBE	RMSE	Correlation Coefficient	Coefficient of Determination
	Deg.	Sec.	$\overline{H/H_0}$	$\overline{n/N_d}$	$?_0$	$?_1$	$?_0+?_1$			CC or r	r^2
Karachi	24	52	0.601	0.694	0.345	0.369	0.714	0.0194	0.4430	0.9884	0.9770
Lahore	31	33	0.555	0.704	0.385	0.243	0.628	-0.0446	0.5965	0.9908	0.9817
Multan	30	12	0.604	0.719	0.422	0.253	0.675	-0.0171	0.3932	0.9960	0.9920
Peshawar	34	00	0.614	0.684	0.569	0.066	0.635	0.0098	0.6361	0.9923	0.9847
Quetta	30	11	0.696	0.771	0.402	0.382	0.784	0.0092	0.5220	0.9958	0.9916

Table 8: MBE, RMSE. Regression coefficients, correlation coefficient and coefficient of determination.

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