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Environmental variables regulating organic carbon dynamics of Sundarban mangrove ecosystem, India

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Abstract

Mangrove forests produce significant quantities of organic carbon in tidally inundated, anoxic soils and maintain large carbon stocks. The influence of the environmental variables on organic carbon is studied and a conceptual model of the dynamics of organic carbon is framed herein. In the mangrove system, various forms of organic carbon are present in soil and water such as soil organic carbon (SOC), dissolved organic carbon (DOC), and particulate organic carbon (POC). Among biotic components, organic carbon present in phytoplankton (OCP), organic carbon in the zooplankton (OCZ) is important. Essential environmental variables like Litter biomass (LB), dissolved oxygen (DO), Primary productivity (PP), Atmospheric temperature (AT), Water temperature (WT) and Tidal height (TH) are considered as factors governing organic carbon dynamics. An univariate statistical correlation was employed to assess the relationships between carbon forms and physical-chemical factors. This was followed by a multivariate statistical PCA (principle component analysis). The results reflect a close inter-correlation among the studied environmental variables and organic carbon.

Keywords: Carbon transformation; Estuary; Mangrove; Organic matter; Phytoplankton; Zooplankton

Introduction

Coastal wetlands are highly productive ecosystems that play a significant role in the global carbon dynamics, water and nutrient cycles (Craft and Casey, 2000; Mitsch et al.,, 2013; Johnston et al.,, 2014). Vegetated coastal ecosystems can sequester and store large quantities of organic carbon including mangroves, seagrass meadows and salt marshes (Fourqurean et al.,, 2012). The pool with the highest organic carbon content in terrestrial ecosystems is the soil organic matter (SOM), a keystone among organic carbon pools and an indicator of soil condition and quality. The worldwide stored soil organic carbon is approximately 1.2–1.5 × 10^{15} kg (1220– 1500 Gt) in the top one meter of soil (Eswaran et al.,, 1993; Batjes, 1996). Mangroves have been identified as potential carbon sequester and are one of the most significant long-term carbon sink of coastal ecosystems (Alongi, 2014). Coastal wetlands, however, are often subjected to anthropogenic

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pressures, including drainage and development (Bao et al.2011; Pearse et al.,, 2018). For the past few decades, the study of carbon cycles as a whole or in part has been an area of research focus of man authors (Dafner and Wangersky, 2002; Smith and Hollibaugh, 1993; Mukherjee et al.,, 2012a). Both organic and inorganic sources of carbon exist in estuaries. Sundarban is one of the world's unique habitats with the luxuriant mangroves occurring in almost every island. The dominant species among the Sundarban mangrove halophytes is *Avicennia marina* (grey mangrove). *Avicenna alba*, *Porteresia coarctata*, *Excoecaria agallocha*, *Ceriops decandra*, *Acanthus ilicifolius* and *Derris trifoliate*. Tree litter (leaves, propagules and twigs) and sub-surface root growth of the mangrove species provide essential organic carbon inputs to mangrove sediments (Alongi, 2007). Average global litterfall rates are usually in the order of 38 mol C m^2 $year^{-1}$ (Jennerjahn and Ittekkot, 2002). Moreover, litterfall would account for around one third of net primary production (Alongi et al.,, 2005a). Significant organic carbon inputs can also be generated by a number of other sources, including allochthonous, for example, riverine or marine material (e.g. seagrass) and autochthonous, such as benthic or epiphytic micro- or macro-algae production, and local phytoplankton water column production (Bouillon et al.,, 2007). Substantial additional POC input could occur through phytoplankton and seagrass detritus imported with tides, depending on local conditions.

In addition, human activities such as deforestation and land ecosystem conversion have resulted in soil degradation and massive loss of organic carbon from the soil (Lal, 2003). One of the biggest exchangeable organic reservoirs is the DOC pool of the oceans. In water bodies, DOC concentration varies along with the magnitude and proportion of autochthonous and allochtonous sources, temperature, depth, season (Sugiyama et al.,, 2004; Dafner and Wangersky, 2002; Zweifel et al.,, 1995). A main link in the global carbon cycle is the transport of organic matter from land to sea (Smith and Hollibaugh, 1993).

Machiwa and Hallberg (2002) made an empirical model on the fate of organic carbon in mangrove forest. They showed that certain parameters which are difficult to calculate under field conditions can be accurately estimated by modelling. Bouillon et al., (2007) and Kristensen et al., (2008) reviewed the organic carbon dynamics in mangrove ecosystem of Kenya and India respectively.

From the past research studies on organic carbon dynamics of estuaries, the interlink between organic carbon pools is not clear. The objective of the present research is to identify the main driving factors behind the organic carbon cycle of estuary and to understand the relationship among them.

Materials and Methods

Study site

The study is based on Sagar and Patharpratima Island, situated in the western sector of the estuary, are the largest deltaic island with anthropogenic disturbances. The area is located between 21˚27′06″ N to 21˚50′18″ N latitude and 88˚14′26″ E to 88˚53′05″ E longitude (Fig. 1). The total

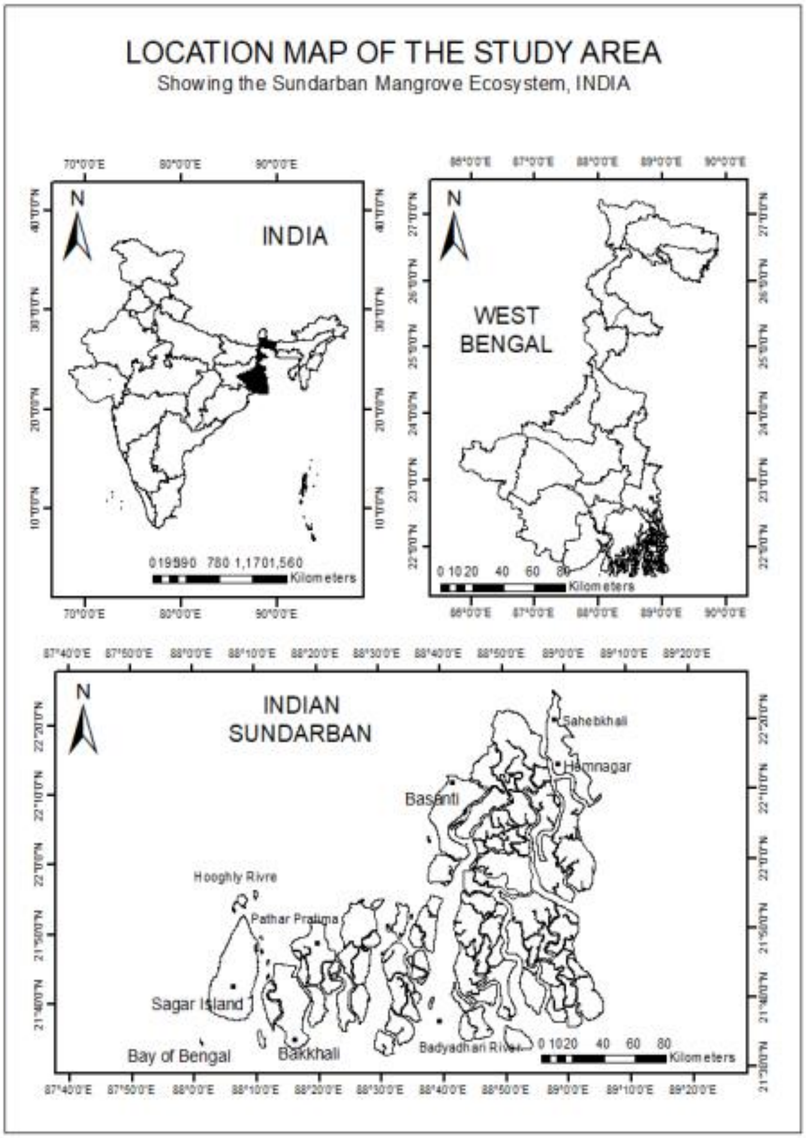

Fig. 1. Location map of Indian Sundarban estuarine system

area of the Sundarbans in India is 3682.76 km^2, including 110 deltaic islands, of which 54 have been reclaimed by humans in earlier (Chakraborty, 1987 and Giri et al.,, 2010). The natural mangrove vegetation cover of both the islands has been altered by human activities and changes in land use by reclamation for cultivation and aquaculture. The seasons in this region are pre-monsoon (March-June), monsoon (July-October) and post-monsoon (November-February) (Mandal et al.,, 2009).

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1.1. Sampling and experiments

Several experimental and survey studies were carried out at the research sites over a span of one year (March 2019 to February 2020) to collect data on LB, various sources of organic carbon (SOC, DOC, POC, OCP and OCZ), PP, AT, WT, TH and DO. Soil samples were obtained at monthly intervals from the field stations at a depth of ~10-15 cm from the mangrove swamps, where tidal flow was observed. The litter from the mangrove forest bed was collected and quantified using square meter nylon nets placed underneath the mangrove trees. Soil organic carbon content were estimated following standard methods. Soil organic carbon was estimated by Walkley and Black method (Walkley and Black, 1934). For chemical analysis, estuarine water samples were obtained from the creeks at a depth of 20-25 cm at various field stations. Samples for DOC and POC were collected in glass bottles in the field and stored on ice container and, in dark condition The samples were taken to the laboratory. The TOC in these samples was estimated using the Analyticjena (TOC) analyzer. DOC was calculated via Millipore GF / F filter (0.45 μm pore size). The water samples were passed through the filter paper and the filtrate was used to determine POC.

At the high tide, plankton was collected from sub-surface water using a plankton net and preserved with iodine solution (phytoplankton) or buffered formaldehyde (zooplankton). Wet and dry weights were determined for quantitative phytoplankton analysis, and phytoplankton carbon content was estimated according to the literature (Jorgensen et al.,, 2000). The Sedgewick Rafter counting method for zooplankton carbon was used to obtain the number of species and the corresponding carbon content was determined according to the literature (Friedler et al., 2003). The light and dark bottle method described by Strickland and Parsons (1972) calculated gross primary output and community respiration in situ.

Model description

A five-dimension conceptual model (Fig. 2) is constructed using VENSIM PLE ×64 computer software (High Performance Systems Inc.). The following explanations describe all physical, chemical, biological components and processes involved in the organic carbon conceptual model.

Litter from the Sundarban mangrove forest deposit at the land-ocean boundary occurs throughout the year. Litter carbon (L carbon) of the surrounding mangrove forest and the death of soil organisms and the death of soil microflora (bacteria and fungi) are the major contributors to soil SOC. Litter carbon (L carbon) is the carbon fraction (C frac) of the litter biomass (L bmas). Inp DSO is regulated by the input rate of dead soil organisms (Inp rt DSO) and dead soil microflora (Inp rt DSM). Some fractions of SOC is lost from the system with some loss rate (Lr SOC). The SOC under anaerobic conditions contributes to the DOC pool through leaching organic acids such as humic and fulvic acids (Lch OA). A significant volume of terrestrial runoff loaded with DOC (Inp rt R), tidal height (TH) and ground water (GD rt) influence the DOC pool. A portion of phytoplankton's primary productivity (PP), as exudation rate (exdn rt) contributes to the DOC pool. Phytoplankton, zooplankton and other excretory products from benthic fauna are decomposed and eventually contribute to the DOC pool (excrtn rt). Certain amounts of POC convert to DOC (bkdn) in the system. The conversion (mi rt) is regulated by temperature of water

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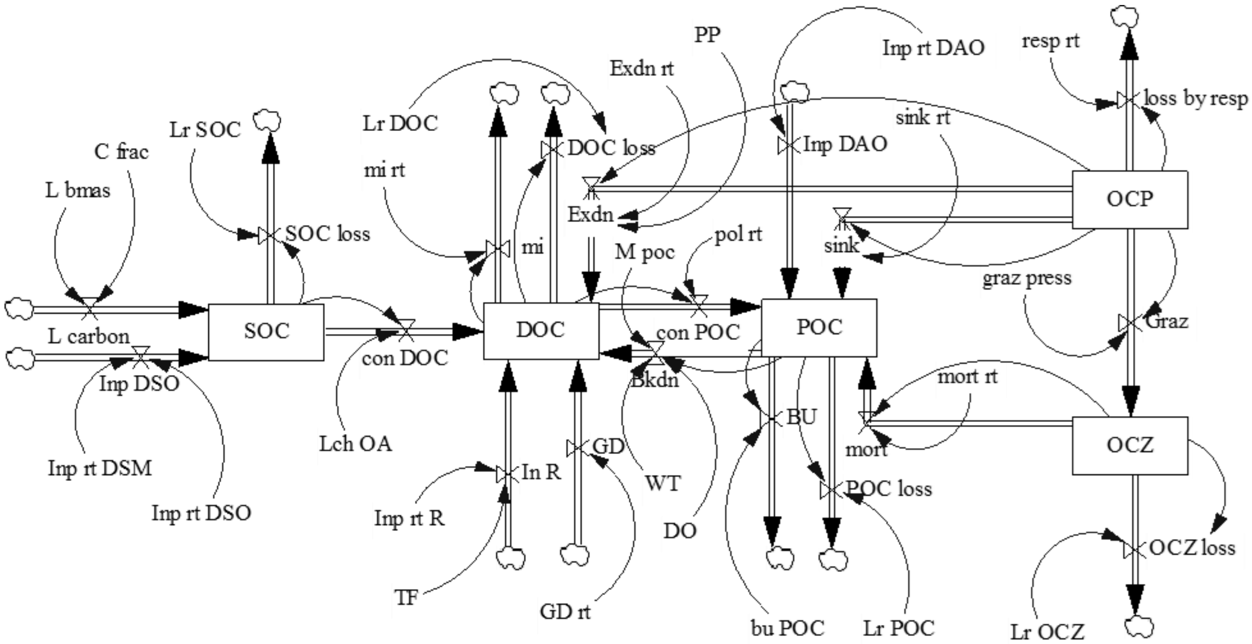

Fig. 2. Conceptual model of organic carbon dynamics of sundarban estuarine system using VENSIM PLE software.

(C frac- carbon fraction of litter, L carbon- input of litter carbon to SOC pool, Inp rt DSM- input rate of dead soil micro flora to SOC pool, Inp rt DSO- input rate of dead soil organism, Inp DSO- inputfrom death of soil organism, Lr SOC- loss rate of SOC, SOC loss- SOC loss from the system, Lch OA- leaching rate of organic acid from soil, con DOC- conversion of SOC to DOC pool, mi rt- mineralization rate, mi rt- mineralization of DOC, TF- tidal flow, Inp rt R- riverine input rate of DOC pool, In R- riverine input of DOC, GD rt- groundwater discharge rate of DOC, GD- groundwater discharge of DOC. Lr DOC- loss rate of DOC, DOC loss- DOC loss from the system, pol rt- polymerization rate of DOC to POC, pol- polymerization of DOC into POC, WT- water temperature, DO- dissolved oxygen, M poc- mineralization rate for POC to DOC, Bkdn- breakdown of POC to DOC, PP- primary productivity, Exdn rt- exudation rate of phytoplankton, Exdn- exudation of phytoplankton, Inp rt DAO- input rate of dead aquatic organism to POC pool, Inp DAO- input dead aquatic organism, bu POC- utilization rate of POC by bacteria, BU- bacterial utilization, Lr POC- loss rate of POC, POC loss- POC loss from system, sink rt- sinking rate of phytoplankton, sink- sinking of phytoplankton, mort rt- mortality rate of zooplankton, mort- mortality of zooplankton to POC pool, resp rt- respiration rate of phytoplankton, Loss by resp- carbon loss by phytoplankton respiration, Lr OCZ- loss rate of OCZ, OCZ loss- loss OCZ from system, graz press- grazing pressure on phytoplankton by zooplankton, Graz- grazing of zooplankton upon phytoplankton

(WT), dissolved oxygen (DO), and the rate of POC (M poc) mineralization (mi). A portion of the DOC pool is consumed by bacteria (BU) with the rate of DOC uptake by bacteria (BU poc). The rest of the DOC is washed out from the system during the tidal flow (Lr DOC). A part of the DOC is polymerized into POC (pol rt). Death of aquatic organisms also contributes to the POC pool (Inp rt DAO). POC is lost from the system by tidal flush (Lr POC). The grazing pressure (graz press) of zooplankton on phytoplankton primarily contributes to OCZ. Loss of zooplankton by mortality (mort) with some mortality rate (mort rt) and some OCZ pool loss (OCZ loss) from the system is controlled by loss rate (Lr OCZ), OCZ contributes to the POC pool. The sinking rate (sink rt) of phytoplankton contributes to the POC pool. The OCP pool is lost due to respiration of the phytoplankton (loss by resp) and the process is controlled by respiration rate (resp rt).

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The different forms of organic carbon (SOC, DOC, POC, OCP and OCZ) along with various environmental variables (LB, PP, AT, WT, DO and TH) collected during the field survey are represented here as a conceptual model of organic carbon dynamic in the Sundarban mangrove system.

Statistical analysis

In order to explain the relationship between different environmental variables and various sources of carbon, a univariate Pearson (linear r) correlation analysis was performed. PCA was done using PAST 4.03 software.

Results

In order to explain the relationship between the various environmental variables and different sources of organic carbon, correlation analysis was carried out (Table 1). The association between environmental variables and various sources of soil carbon indicated that the SOC was

Table 1. Correlation of all the variables considered for the study.

	SOC	DOC	POC	OCP	OCZ	LB	PP	DO	AT	WT	TH
SOC											
DOC	0.461										
POC	-0.559	-0.484									
OCP	0.485	-0.050	0.356								
OCZ	-0.254	0.078	-0.435	-0.876							
LB	0.711	0.730	-0.434	-0.105	0.080						
PP	-0.776	-0.407	0.155	-0.675	0.555	-0.292					
DO	0.754	0.825	-0.576	0.185	0.018	0.603	-0.616				
AT	-0.647	-0.678	0.538	-0.137	0.138	-0.658	0.440	-0.784			
WT	-0.569	-0.752	0.497	-0.117	0.118	-0.667	0.337	-0.787	0.963		
TH	-0.631	-0.015	0.401	-0.407	0.123	0.178	0.502	-0.461	0.151	0.101	

significantly correlated with LB (0.71) and DO (0.75) and negatively correlated with TH (0.63). DOC was positively correlated with LB (0.73) and DO (0.82) and negatively correlated with PP (-0.41) and WT (-0.75). AT (0.53) and TH (0.40) were positively associated with POC and negatively correlated with DO (-0.57). OCZ showed positive correlation with PP (0.56). There was a significant negative correlation (–0.867) between OCP and OCZ. The seasonal variation of the

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environmental variables and the organic carbon pools of the Sundarban mangrove ecosystem is shown in the Fig. 3a, 3b, 3c, 3d and 3e.

The variance pattern of the studied variables across seasons is examined by a PCA biplot (Fig. 4). The overall variance described corresponds to 50.67 % for the aforementioned variables. It revealed that in the months of March, April, June and February, maximum variation was observed. In relation to environmental factors, the late monsoon and winter months were stable.

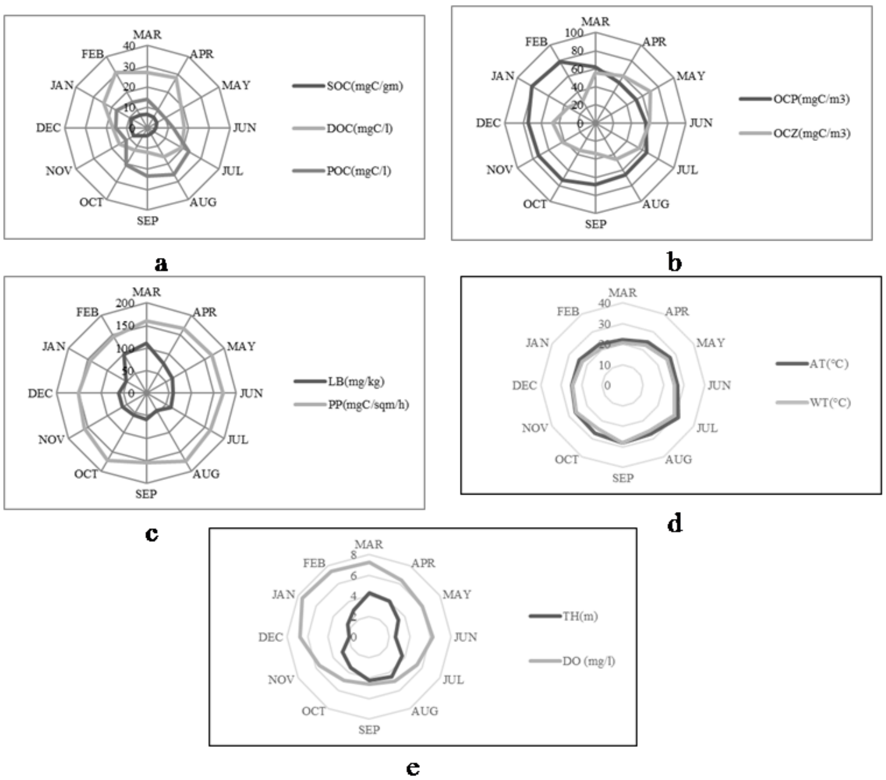

Fig. 3. Radar plot shows (a) Fluctuation of SOC, DOC and POC during study period, (b) fluctuation of OCP and OCZ during study period, (c) fluctuation of LB and PP during study period, (d) fluctuation of AT and WT during study period, (e) fluctuation of DO and TH during study period.

Discussion

The PCA biplot showed that December to March, that is the postmonsoon and earlier premonsoon months, experienced maximum variation in SOC, DOC and OCP along with LB and DO. Mitra et al., (2018) studied on a potential carbon scrubbing system in Indian Sundarban mangrove ecosystem. They observed that the OC showed a distinct seasonal pattern with highest value in monsoon followed by postmonsoon and premonsoon.

It was observed that summer experienced increased that microbial activity due to a high temperature leading to increased rate of mineralization (Sorensen et al.,, 2018; Thomas et al.,,

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2018; Yam and Tripathi, 2019). The present findings are in agreement with above observations. It is seen in different regions that nutrient availability in mangrove soils decreases from the landward zone to the seaward zone along the estuarine gradient of tropical estuary (Asp et al.,, 2018). Tidal inundation has a large effect on the species habitat zonation in the mangrove areas (Leong et al.,,

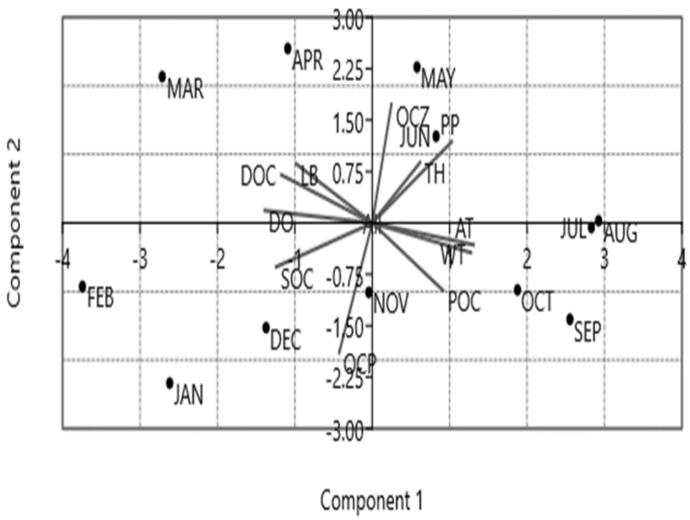

Fig. 4. PCA biplot showing the components using pooled data for 12 months

2018). The May and June, the premonsoon months showed OCZ has maximum variation along with PP and TH. The month of monsoon experienced variation in POC along with AT and WT.

In the monsoon months due to rain and water runoff, water logging condition often prevails in the adjoining mangrove forest substratum of estuary and prevents the penetration of atmospheric oxygen, lowering the activity of bacteria and fungi, and other detritivores present in the soil (Beimans et al.,, 2019). Community respiration also remains high in these months (Sullaway and

Edwards, 2020). In the absence of physiological stress by sulphide and salinity, soil nutrient availability is considered as the key factor for determining mangrove biomass and productivity (Chen and Twilley, 1999). Due to inundation in the monsoon months anaerobic conditions in soil exist (Maji et al., 2020). Pore spaces in the soil are filled with water and rate of oxygen diffusion is reduced enormously (Masilamani et al., 2020). It is evident from the arlier studies that the microbes utilize OC as food source. Since the decomposition rates are slow and organic load from the seven main rivers of the Sundarban mangrove system increases during monsoon, the overall load of organic carbon of estuary is increased during monsoon.

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During post monsoon temperature remains low. Mangroves litterfall is increased at that time; also microbial activity is lowered as a result SOC values remained high during this period. Dissolved oxygen content is high and temperature remains low in the postmonsoon, diffusion at the air-water interface occurs at high rate along with community metabolism (Berg et al., 2019). Thus the organic carbon content is moderate during this period.

Field results showed that in postmonsoon when phytoplankton blooms occur, the zooplankton population is moderately high. Then grazing pressure upon phytoplankton causes a decline in the number of phytoplankton. Zooplankton reaches its peak during premonsoon in the Sundarban mangrove ecosystem (Mandal et al., 2012).

Conclusions

Across the intertidal landscape, mangrove forests clearly contributed the most to POC through LB. The cycling of organic carbon along with the adjacent mangrove forest in the Sundarban mangrove ecosystem is an integrated phase of the soil, sediment, water and biota. The LB and AT are very crucial for the soil system, while WT, TH and dissolved oxygen are the regulating factors for the water system. In the spatiotemporal modelling aspect, this can be further demonstrated to understand the dynamics of nutrients with abiotic factors that in turn influence the system's sustainability. This research can further be extended with the inclusion of long term study based on simulation modelling. The conceptual model present here represents the interaction among environmental variables and organic carbon pools of the Sundarban mangrove ecosystem.

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United Nations Environment Programme—Present and Future

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Abstract

Environmental issues are posing a grave challenge to humanity since few decades now. In this regard, the role of United Nations Environment Programme (UNEP), the international institution coordinating these concern has been an important subject of study. A number of studies since the very inception of UNEP, have tried to examine and reform its functioning to meet global challenges. The purpose of this paper is to review existing literature on this subject. It summarizes the views of different analysts who have devoted their study to an understanding of the nature, functions and shortcomings of UNEP. It further combines the recommendations suggested by them in order to strengthen UNEP or to replace it with UNEO. On having observed the arguments meticulously the paper synthesizes reform recommendation. It also tries to address the gap in existing literature that tends to be arbitrarily tilted towards the study of functions rather that structure of UNEP and makes recommendation for the same as well.

Keywords: UNEP, UNEO, environment, mandate, assessment, cluster, autonomy

Introduction

The years 2019-20 are marked by unprecedented incidences around the globe, definitely COVID-19 remains most crucial and has contributed to a paradigmatic shift in every horizon. Yet, the question of Environment and its concerns remained as crucial as always with the heartbreaking episodes of Amazon, Australian and Californian forest fires sending chills among all, the rising level of air pollution, heat waves and consequent protests of such by the youth, not to mention the name Greta Thunberg here, have all rendered a review of the working of the "anchor" environment organisation UNEP imperative.

The purpose of this paper is to review the existing literature which largely trend on the performance of UNEP and focused on dimensions like its functions, relation of style of leadership within UNEP and resulting efficacy of the organisation, practices of monitoring by UNEP and how fruitful are its coordination of multilateral agreements. The literatures also study the shortcomings of UNEP in managing environmental affairs at the global level, and a number of them vary from each other in the recommendations they make for the same, while some voice strongly for establishing a world environmental organisation in place of UNEP others claim for upgrading UNEP into UNEO.

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In this paper, we would like to collate the views of the literatures and try to summarize the best possible recommendation for making UNEP at par with the global environmental challenges. The gap that exists in the present literatures will be assessed and explained and how most of them except a few like that of Bauer (2009), does not throw sufficient light in the institutional and structural study of UNEP as a limiting factor in its functioning. In conclusion, those gaps would be addressed to provide a strong foundational recommendation that would prepare us better to nurture Mother Earth for a golden future of humanity.

Assessing the Performance of UNEP

The UNEP, is the recognised global authority on environmental issues, thus in-charge of formulating international environmental agendas, establishing comprehensive and practical execution plans for fulfillment of goals of Sustainable Development within the United Nations system and serving as a watchdog over environment safety protocols. Established in 1972 and headquartered in Nairobi, Kenya, its mission is to provide global leadership and encourage partnership, cooperation and confidence in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life.

Discharge of Essential Functions

UNEP, in 1972 was established as the "core", or "anchor institution" [2], at the global environment level. Its most vital responsibility is the collection, organisation and distribution of environment related information, coordinate actions and ventures of nations within the UN arrangement. The extant literature reviewing the performance of UNEP varies widely, wherein some glorifying it, in terms of its achievements as the most splendid UN organizations [16], well-regarded institution [16], quite effective [16] and an impressive success provided the limited mandate, resources and authority it has at its disposal [21]. Whereas, some others label it as rather outdated, overburdened, geographically distant and lacking in resources, authority and funds [12], "peanut-sized [18], "weak agency" [21] with misspent limited resources and a credibility gap (UN 1997). With the increased instances of environmental failures, it will not be wrong to state that UNEP has not been wholly successful in the discharge of its functions.

Ivanova (2015), assesses UNEP's performance in three core functions:

Supervising, examining and reporting on the global environment issues and concerns;

Preparing action plans and regulating standards, policies, protocols, agreements and guidelines; and nurturing the capacity of its own as an institution which could tackle and resolve present and future environmental problems.

Supervision, Examination and Reporting

Regarding its function of supervision, examination and surveillance UNEP is required to offer advice and consultation on environmental policies, issue prompt warning and safety protocols on environmental threats, and to mediate plus encourage cooperation and joint ventures between nations on environmental issues making efficient use of the most advanced scientific and technical capabilities available (UNEP 1997b). In this regard it can be said that the UNEP has been productive

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in monitoring, assessing, launching environmental agreements [13], assessment of global environmental issues [12] and UNEP's planning for monitoring and evaluation is said to be critical on performance of UNEP GEF projects in Kenya [14]. Its publication, Global Environmental Outlook (GEO) has been appreciated as one of the two most respected environmental outlook publications available presently [20]. Hence, the existing literature highlights effective performance of UNEP in this sphere.

Preparing action-plans and regulating policy processes

As an authority institution on environment, it is an essential function of UNEP to set agendas and manage policy processes. The function is critical to gain agreement on standards, policies and guidelines [13].

However, it is this field where UNEP has not been able to be sufficiently effective. UNEP has not been successful in coordinating agreements effectively in its two key areas: coordinating multilateral environmental activities and those of other international organisations [13], its efficacy in coordination have been considered low [2]. In this regard, Andresen and Rosendal (2009), pointed out that the secretaries of smaller multilateral environmental agreements were more satisfied with the role of UNEP than the bigger ones.

UNEP has made efforts for increased "coherence" and "coordination" of multilateral environmental agreements but the success is very limited. [1]

Capacity building

UNEP, is helping environmental ministries around the world in building institutional capacities as a response to the requests by the governments. [13]

So, in the field of capacity development of nations to deal with environmental challenges UNEP has been quite effective.

Style of Leadership and its Impact on Performance

An evaluation of the style of leadership practised in UNEP and its effect on its performance indicate that, transformational, charismatic and democratic leadership is practised here and it does have an impact on the organisations' performance [11]. Gachingiri (2015) further establishes that majority of the respondents (82.93%) revealed that management in UNEP does not exhibit elaborate ways and method to enjoin people work together collectively at a common endeavour.

Secretariat of UNEP

The General Assembly has provided UNEP with a "small secretariat" of some 400 members with a Governing Council of 58 members that represent the five United Nations Region. UNEP Secretariat

handles several issues and is therefore a very efficient international bureaucracy, which yet remains constrained by a series of factors. The factors are the subordinate position of the

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secretariat providing a moderate degree of organisational independence and authority to it, a scanty budget further has contributed to make many of its initiatives helpless and lack of mandate has rendered policy implementation difficult [4]. Even though the Secretariat has been helpful in shaping the cognitive sphere of international environmental awareness by and large it remains very short in the fulfilment of its duties.

Reviewing the Shortcomings in the Functions of UNEP

An analysis of the functions of UNEP through different dimensions has quite clearly revealed the shortcomings in the functions of the UNEP. The existing literature clearly points towards the inadequacy of UNEP to function as an authority in global environmental global governance. The paper further tries to explore the shortcomings or limiting factors that inhibit the organisation to function fruitfully.

Formal status: The first and foremost limitation of UNEP as pointed by many is its status as a UN programme rather than as a specialised agency of the UN [13]. A similar view is presented by Nils Meyer-Ohlendorf and Markus Knigge (2007) as he states because of its current institutional status, UNEP in its current form is not able to fulfil its coordinating mandate. The lack of authority has curbed the programme's ability to efficiently meet current and emerging environmental challenges.

Hence, in view of the observations stated above, it is evident that the formal status of UNEP as a programme is a strong limiting factor for it to perform its coordinating mandates.

Governance: The governance structure of UNEP includes three bodies-the governing council, secretariat and the committee of permanent representatives. Most often these representatives have little environmental knowledge and have other duties to perform. [21]

Further, the unclear relationship between the permanent representatives and the governing council limits the functioning of UNEP [13]. The current UNEP Governing Council (GC) has 58 members and is not accountable [17]. The governance of UNEP is thus weak and inefficient in managing the work of UNEP and has thus contributed towards the failure of the organisation.

Financial structure: Weak financial resources available at the disposition of UNEP, and its complete dependency on voluntary contributions of individual states are strong factors curbing its powers. One of the root causes of UNEP's problems may be the organisations financial structure [13]. UNEP remains ineffective because of its limited finances is pointed by Ohlendorf and Kingge (2007) as well. The importance of finance as a resource for productive and fruitful functioning of any organisation can never be undermined and UNEP's dependency here speaks volume of the disregard and lack of due attention the body receives in the UN system.

Organisational structure: A number of issues in this regard have been highlighted by Ivanova (2005) like the functional responsibilities of many major departments are not very clear, the system lacks

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clear delegation of authority, lack of coherent and comprehensive presentation of the programme budget, oversight of assessment and assessment of results is fragmented thus rendering policy making a difficult task to behold. Gachingiri (2015), in her study also stated that the management of UNEP lacks methods for collective endeavour. Organisation of UNEP is not well structured and monitored to enable it to function as a global manager of environmental issues.

Location: Its geographic isolation from other UN operations further inhibits its capability to effectively coordinate and mediate actions [13]. The location, Nairobi is not a very desirable for top-notch professionals, the long distance require frequent travel of the leaders thus entails financial burden and prolonged absence of the leadership. The location, even though having set up with a pious thought of basing UNEP in an African country has not yielded due results and has actually backfired as a contributing factor to its limitation.

Thus, UNEP has dearth of autonomy and authority to act as global environment authority owing to several factors, which are limited and irregular budget; fragile legal status; and the overlap of its instructions and commands with those of many other international environmental organisations that have similar responsibilities but are unwilling to defer to UNEP [19,9,3,5,6,2]

Recommendations

In light of the shortcomings observed, a number of recommendations have been forwarded to overcome this limitations, while some of these contemporary prescriptive reform initiatives are remedial and seek to make modifications in the existing structures and functions of UNEP, most of them have recommended for a complete upgradation of the UNEP into UNEO (United Nations Environmental Organisation) or replacement of UNEP by UNEO. The advocates of transformation of UNEP into UNEO further vary among themselves as some prepare case for the creation of a World Environmental Organisation at one go, while others debate for the conversion of UNEP into UNEO in a phased manner. A look into some of the dominant literatures that deal with recommendations to heal UNEP would be interesting here.

Modern reform suggestions pertaining to environmental governance can be divided into two groups: First group takes UNEP as the starting point for system wide reform, for example the UNEO initiative, and the second group proposes a thorough system overhaul, as the proposed World Environment Organization, Global Environment Organization and Global Environmental Mechanism (GEM) [13].

Ivanova (2005), claims that mere upgradation of UNEP into UNEO, is not sufficient. Hence, she recommends that reforms should be multifarious, varied and stratified, which will focus on the essential functions of effective global environmental governance and creation of suitable institutional arrangements. In the same line, she proposes the following reforms:

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Policy options for governments and the International Task Force on Global Public Goods

Establish an extensive assessment plan of global environmental governance which involves reforming global environmental governance demands a holistic assessment of the present system's strengths and weaknesses, challenges, imitations and of UNEP's effectiveness in fulfilling its mission as an anchor institution. This evaluation will produce an "analytically sound" and "politically visionary" set of recommendations on how to strengthen global environmental governance.Create a global environmental information clearing house i.e. a central organisation to establish data protocols and as a storehouse to maintain comprehensive information is necessary.

Create a global environmental capacity clearinghouse. For capacity building, an integrated point of information for environmental governance must be created, that will plan, execute and manage technical assistance activities, regulate and coordinate supply and demand of services and will call attention to best practices on varied projects.

Cluster institutions. In the present scenario, it is imperative that expertise and resources are pooled together under the lead of certain head institution. This combined effort will produce better results than fragmented and often competitive efforts of individual organisations [10,21].

Policy options for UNEP

Initiate an independent strategic review of UNEP's role. An independent strategic review, is the need of the hour to examine UNEP's role and performance, history of the organization, current and future needs and trends and defining plan of action based on its progress, constraints and opportunities. It would help support transition to more accountable leadership and improved management practices.

Consolidate financial accounting and reporting. A comprehensive and clear reporting of finances is crucial to the reformation of UNEP, so as to offer an idea to the donor countries as well as all stake holders of the use of money provided to it.

Restructure Organisational governance. An inclusive structure, exclusively devoted to the functions of UNEP and thus less burdened is the need of the organisation. It could be a governing council or a Global Ministerial Environment Forum, or an executive board of around 20 members to analyse global issues, evaluate global needs, spot gaps, recognise global priorities and synthesize strategies to address them.

Kihuha (2012), suggests to enhance monitoring and evaluating process, responsible authorities should consider employing experts or upgrading skills of their technical staff to ensure effective processes. He also raises point for active role of various stakeholders and management in monitoring and evaluation of UNEP.

Gachingiri (2015), while studying the impact of leadership on the performance of UNEP suggested that the management should strive for at using specific ways and methods to guide the collective working of its staff, they should be more conscious towards the development and needs of the staff and that the UNEP's performance is largely affected by "extraneous" factors so they need to apply different methods and techniques to increase organisational efficiency.

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The above are the reformatory pieces that prescribe initiatives within the UNEP system to make it more effective, there is another category of literature that strongly argue for an "upgradation" of the very status of UNEP into UNEO with major structural and functional changes accruing to the body.

Debate and Case for a World Environmental Organisation:

Biermann (2011), presented a strong debate for a World Environmental Organisation. He presents his debate by highlighting the pathetic condition of environment today and the shortcomings of the

present international organisations in dealing with them. He then chronologically traces the "forty years' debate" centralised on the need of a World Environmental Organisation. He prepares three models to support his argument and moves on with numerous arguments to call for upgradation of UNEP to UNEO [7]. Similar line of argument is presented by Meyer-Ohlendorf and Knigge (2007) who look into the creation of UNEO as a reformation of UN itself and sets the debate in a broader political context. They have in length discussed the features of UNEO, distinguishing it from UNEP and presented case both in favour as well as against upgrading UNEP into UNEO. The study by Olsen & Elder (2012) presents case for upgrading UNEP but in a phased manner which according to them will be politically more feasible.

Need for a World Environmental Organisation

Most of the studies in line with demand for World Environmental Organisation put a lot of emphasis on the alarming situation of environmental degradation and the consequent disaster it may call for humanity. Human beings influence global biogeochemical forces as powerful agents of earth system evolution [7]. Biermann (2011) strongly stated that contemporary policy makers have to deal with one of the largest political problems humankind has ever dealt with: protection of the entire earth-system including most of its subsystems, building of firm institutions that could assure a guarded transition, a coevolution and coexistence of natural and social systems at universal scale. It is looked upon by him as a challenge of earth system governance, as a new standard to explain this unique challenge of planetary coevolution of humans and nature. In this scenario, International Organisations become most crucial in conducting research, synthesizing the data, policy framing, assessments, implementation and dissemination of information to all the concerned stake holders. UNEP was established as a basic program of UN, which is devoid of any legal personality or budget and is only a "small secretariat"

At UNEP's Governing Council Meeting held in February 2007, regional organisations like European Union restated the need of an organisation like World Environmental Organisation, asserting that mere strengthening of UNEP would be insufficient to address future challenges.

It emphasized that an upgrade of UNEP into a UNEO, with strong, ample, regular resources and with appropriate international position, would qualify the organization to fulfil its mandate and meet the expectations of developed and developing countries [15]. The existing international environmental governance architecture aimed at addressing environmental issues at the global level is “disjointed, fragmented and lacks authority to effectively combat environmental degradation” [17].

Thus, a review of the literatures arguing for World Environmental Organisation, together converge to the fact that the existing International environmental governance is severely lacking in the discharge of its functions and the catastrophic situation of environment calls for an immediate remedy of the same. Each of the studies highlight the inadequacies of the functioning of UNEP on various grounds and thus develop case for an upgradation of it.

Fifty Years Debate on a World Environmental Organisation

Biermann (2011), traces the ongoing debate on World Environmental Organisation and held that the debate in 2011, the time he prepared his study was 40 (now 50 years) old.

First proposal for such was raised by George F. Kennan in 1970. He insisted for an International Environmental agency including a small group of advanced modern nations, which resulted in the establishment of UNEP in 1973, by virtue of a resolution adopted at the 1972 Stockholm Conference on the Human Environment. UNEP is established not as an international organisation but a subsidiary body of the United Nations General Assembly reporting through Economic and Social Council.

The Declaration of the Hague (1989), initiated by the governments of The Netherlands, France and Norway, revived the demand for a more powerful authoritative institution for international environmental policy making and effective majority rule.

Again, several countries like Brazil, Singapore, Germany and South Africa, at the 1997 Special Session of the UN General Assembly on environment and development collectively submitted a joint proposal demanding an international umbrella organization in charge of environmental concerns, with United Nations Environment Programme as a major pillar.

The debates broadened and deepened in 1990s, with increasing reports of environmental failures calling for brain storming on the functions of a world environment organisation. In the new century, the demand was again stressed by the French government in 2003 to replace UNEP by a “world environment organisation”. The proposal was reiterated by the 2007 Paris Call for Action during the Citizens of the Earth Conference for Global Ecological Governance, and received support by an intergovernmental organisation called Group of Friends of the UN Environment Organization. Following the Conference Citizens of the Earth, a “Group of Friends of the UNEO” was created which has – as of February 2007 - gathered over 50 countries. The group will, “take action to strengthen and transform UNEP into a UNEO, in the context of UN reform.” [15’.

In this debate, the critics are equally sound and loaded with arguments. Calestous Juma, former head of the secretariat to the Convention on Biological Diversity, argued that those who demand for a central environmental authority are diverted from immediate environmental problems and

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also do not realise that centralizing institutional structures are an "anachronistic paradigm", thus calling our attention to the fact that such an idea of centralised structure is outmoded and hence does not suits present circumstances and needs. These concerns were supported by Sebastian Oberthür and Thomas Gehring (2005) based on institutional theory. Konrad von Moltke (2005) or Adil Najam (2005) have argued against centralised institutional architecture and worked in favor of decentralized institutional clusters which will adequately deal with diverse range of environmental issues instead of addressing all problems to one central organization.

Thus, the debate for a World Environmental Organisation is still on with both sides remaining steadfast with their arguments. The studies do converge on goal that is the need for reformation of the UNEP [13,7,15,17]. They only differ in the objectives or the path they suggest for the same while some suggest a centralised institutional authority [7,15] others call for a decentralised one [21,16] or for movement towards UNEO in a phased manner [17]. Within the UN system itself the issue is being seriously considered and together with a number of stake holders like country delegations, scientists, business leaders, non-governmental entities among others have summarised several proposals for overcoming the shortcomings, amongst them the most prominent being the establishment of UNEO.

Model for World Environmental Organisation:

Having realised the need for a World Environmental Organisation, the task which the studies further took was to explore the best possible model for the same. While some explored the available models and then converged on the need for UNEO with complete arguments [7], others emphasised on UNEO and focused on understanding its structure and functions that could provide best responses to the needs of the hour [15], and ones like Olsen & Alder, 2012 reiterated the case of upgradation of UNEP in a phased manner.

Biermann contended that all possible proposals for a world environmental organisation can be categorised into one of the three different models which differ from each other in the degree of change they propose.

Least radical proposals advise upgrading UNEP to a specialised UN agency with full-fledged organisational status like the World Health Organisation or the International Labour Organisation as suitable models. This new agency would incorporate in itself "norm-building" and "norm-implementation" processes, differing from UNEP's 'catalytic' mandate that limits the body's project implementation authority. The body will have legal and political powers as a UN special agency and thus could impose certain regulations agreed by majority vote to be imposed on member countries. These powers exceed over UNEP which is not authorised to use legal instruments.

To check the substantive and functional overlap between the different international institutions involved in global environment governance, some observers assert for an elementary reform and support the creation of a more centralised governance architecture for the integration of several existing agencies and programs into one all-encompassing world environment organisation.

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A hierarchical intergovernmental organisation to deal with environmental issues empowered with majority decision making along with the powers and authority to enforce its commands vis-à-vis nations those which do not adhere to international agreements on the protection of global commons. The Hague Declaration of 1989 raised demand in this direction only for an environmental agency with sanctioning powers.

On observing the different models, Biermann (2011) presented his own case for a World environmental government. He suggests upgrading UNEP to a specialized UN agency would follow the policy of functional specialization within the UN system. The establishment of a UN specialised agency could strengthen global norm-building and institutionalism. An independent UNEO, by helping to safeguard the special interests and needs of individual programs and organisations would

contribute in making the Earth system governance much stronger. Governments could equip the new agency to coordinate and regulate multilateral environmental agreements which would then form the "global environment law code" under the UNEO. Thus the UNEO assembly, would be enabled to develop a common reporting system for all multilateral environmental agreements and a common dispute settlement system on mutually, cooperatively agreed guidelines and protocols. UNEO could also upgrade the overall execution of earth system governance for example by a common global reporting system on the condition of the environment and on the status of implementation in different countries. UNEO could help smaller developing countries in making their participation in earth system governance strong and more effective, it would also help them build specialised "embassies" at the seat of the new agency. Decision-making procedures based on North-South parity— veto rights for both North & South as a group—could ensure that the UNEO would not evolve into a new form of eco-colonialism.

Possibility of a "world organisation on sustainable development", building on a merger of UNEP and UNDP is likely to harm environmental issues in the long run on account of the unequal size, resources and functions of both, he fears that the issue of "environment" would be weakened in comparison to "development". Therefore, we need a UNEO, with an aim to preserve environmental resources within the development process. It would thus have to encompass more than purely environmental rules, but address the development concerns of South as well.

Nils Meyer-Ohlendorf and Markus Knigge (2007) have provided a detailed analysis of the structure & function of UNEO.

Core features of UNEO

The study offers an understanding of the core features of the proposed UNEO that has emerged in discussion in recent years.

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Legal Basis: UNEO is to be established as a Specialized Agency of the UN, according and in line with Article 57 of the UN Charter that would place it under the command of ECOSOC with a definite degree of autonomy.

Institutional Architecture: The institutional architecture of the UNEO is to include Plenary, Executive organ and a Secretariat, with a defined decision making process.

Mandate and Functions: The UNEO would be an umbrella organization and would thus, as a decentralized institution, respect the independence of MEAs. It would help to collectively pool the scientific knowledge on environmental issues and take lead in defining global environmental strategic guidelines to promote cooperation, coordination and synergies between countries.Funding: UNEO budget would be based on assessed contributions, whereby every member state would have a legal contribution to pay an agreed contribution thus ensuring the financial resources and autonomy of the institution.The major advancements which the agency would have over the programmed is arguably its legal personality based on an international treaty thus with a more authoritative mandate, structural advancements with a plenary body comprising full membership of all member states providing a full voting right for all and a promised budget to provide it with financial autonomy.

Case for UNEO

The study vividly explains the cause of UNEO and the benefits such a body is likely to bring to the human race:UNEO with its improved agenda setting and coordination capacities would integrate environmental policies with other policy areas like poverty eradication and economic development. With its legal authority, the UNEO would be able to generate participation of all stakeholders in international environmental discussions and ensure reporting by all.

It will have more developed scientific base and multidisciplinary response structure

It will allow more scope for developing countries to have a say in these issues.

Financially sound UNEO will have better focus on tasks at hand and thus ensure better coordination of tasks.

On similar lines of demand for upgradation of UNEP is the study of Olsen & Elder (2012), the point of departure they have is the case they present for a phased approach for the same which according to them is more politically feasible and easier to implement in the short term.

Case for a phased approach

In the first phase, UNEP's Governing Council would be provided with universal membership, and to be upgraded into a specialised agency in the second. In their proposal they have connected both steps and recommend that they should be undertaken in succession. The first phase is expected to create necessary space and momentum for the subsequent one, as by increasing the representation of the GC the member states would be sufficiently convinced of the merits of granting independent decision making authority to GC. Thus, implementing both phases would create more authority around IEG, and would create a body that could cluster multilateral environmental agreements (MEAs) and improve the fragmentation, which is now a defining feature of environmental governance.

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Plan for phased upgradation:

Phase 1—Universal Membership: The first reform phase will equip the UNEP Governing Council with universal membership, which would increase the legitimacy and credibility of environmental decision- making. This increase might result in more cumbersome decision-making, which could be remedied by adoption of a qualified majority voting system. Another purpose of universal membership is to cluster thematically-related MEAs within its universally representative forum.

Phase 2--- Specialised Agency: In the second phase, UNEP is to be transformed into a specialised agency. This could be introduced by a General Assembly resolution, which could create a UN Environment Organisation (UNEO) furthered by a treaty which would establish a fully-fledged World Environment Organisation (WEO). UNEP (then UNEO), with a specialised agency status would be legally autonomous which will enable it to approve its own decrees and measures, without depending for approval by any another higher level body such as ECOSOC or the GA.

Conclusion

The paper intended to explore existing literature to study the performance of UNEP, the existing international organisation to manage environmental issues, an analysis necessitated by alarming rise of environmental catastrophes in recent times. An observation of a few of these, clearly establish the fact that UNEP has not been able to perform effectively owing to a number of shortcomings it is infested with which ranges from its mere status as a program, lack of mandate, funding, distant location etc. The studies have vividly examined the nature of this shortcomings and the causes behind them. They further tried to explore the way out of it and have recommended several proposals for its reform which differ from each other in many respects, some have exclusively raised the demand for a complete upgradation of UNEP into UNEO, others have suggested radical reforms within the existing UNEP system.

However, barring a few like the study of Bauer (2009), most of the studies have not paid due attention to the issues of the structure of UNEP exclusively as a limiting factor in its effectiveness and have only considered it as one of the components which need reform among many other shortcomings of UNEP. Most of the studies are focused on the functional aspect of UNEP—its functional effectiveness and limitation. Such, neglect of structural dimension of UNEP and exclusive focus on its functions has cost expensive literary deductions that could have contributed a universe of literature that would exclusively be devoted to the structural study of UNEP—its structural effectiveness, shortcomings and ways out of such shortcomings.

Thus, more dedicated analysis of the structure of UNEP is the need of the hour which can sufficiently offer insight into its efficacies, limitations and thus generate conclusions as to best ways to improve them within the UNEP system itself or in the proposed UNEO. The recommendations based on the observations may include these strategies.

UNEP needs profound and immediate overhauling of its certain core areas for example in its official status as a mere program, scarce resources, location, structure to name a few. Such core areas are to be immediately catered to without any further political delay. Reform of such core

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areas can most positively be achieved with a GA resolution that could make provisions for increased mandate of UNEP, provision for organising its financial base and reforming its structure to provide more authority and autonomy to the Secretariat. For issue concerning its official status, location, membership of the governing council among others, I reinforce the need of a World Environmental Organisation which should be seriously considered and discussed by all the stakeholders and concrete efforts should be made for its realisation in the long run. The move towards World Environmental Organisation or UNEO, may cost time as it involves affirmation of multiple stake holders and includes political complexities, however a resolution directed towards strengthening core areas of UNEP itself need not face such issues and hence can be achieved at the earliest. The reform at this stage is within the UNEP system itself and hence is less problematic to achieve.

Subsequently, based on the experience gathered from the activities of the reformed UNEP, we would be better positioned to address the needs of the proposed World Environment Organisation and thus make arrangements accordingly to meet challenges of the time.

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Assessments of Bioaccumulation Factor (BAF) for heavy metals (Pb and Hg) in an aquatic insect *Laccotrephesruber*: A major faunal component for three contrasting freshwater aquatic ecosystems of West Bengal and Odisha

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Abstract

Although insects harbor almost all the terrestrial habitats but occur with negligible abundance in the aquatic environment mainly because of their tracheal mode of respiration. The present paper has attempted to find out the Bioaccumulation Factor (BAF) of a major aquatic insect species, *Laccotrephesruber* which inhabits in higher densities in three distantly located freshwater bodies having contrasting ecological factors overcoming even different environmental odds, especially the loads of two toxic heavy metals such as lead (Pb) and mercury (Hg).Collection and preservation of the aquatic insects alongwith estimation of different water quality parameters were made following standard methodologies (APHA, 2005). The heavy metals of the water, soil, selected aquatic plants and insect species were determined by Atomic Absorption Spectroscopy (AAS) from three selected study sites of [(1) a water impoundment – Rissia Dam in Odisha, (2) a large water body at Tamluk, West Bengal, and (3) a large pond at Haldia, West Bengal].In this study, above three study sites were selected in order to determine the concentrations and variation of two heavy metals (Pb and Hg) and their trend of accumulation in water, soil, aquatic plants and one aquatic insect species. After undertaking a yearlong (March'2019 – February'2020) field survey, Bioaccumulation Factors (BAF) of those heavy metals in an aquatic insect species, *Laccotrephesruber*and were deducted along with the recording ofdifferent pronounced ecological parameters (water quality – pH, temperature, conductivity and Total Dissolved Solids). It was seen that, lead (Pb) was found to be higher than mercury (Hg) in all the structural components (water, soil, vegetation and insect) of the three aquatic ecosystems including within the body of*Laccotrephesruber* ofall (slight exception for soil of Rissia Dam). Besides, the concentrations of both the heavy metals were highest in the study site 3 (within industrial belt) followed by study site 2 (under the human activities) and study site 1 (in the natural undisturbed environment).From the BAFanalysis of *Laccotrephesruber*, it is seen that – (i) Hg is very bioaccumulative than Pb in Rissia Dam; (ii) Pb is moderately bioaccumulative than Hg in Tamluk; and (iii) Pb is very much bioaccumulative thanHg in Haldia.

Keywords: Aquatic insects, Hemiptera, Coleoptera, heavy metals, Bioaccumulation Factor (BAF).

1. Introduction

Aquatic insects as bioindicatorsare amongst the most frequently used groups in the biological assessment of water quality worldwide [1]. They offer a spectrum of responses to different degrees of environmental stress and change over time [2].Some studies have reported that aquatic insects are very effective at detecting anthropogenic disturbance and habitat quality, which is mainly due to their sensitivity to various factors responsible for water quality changes [3].Aquatic insects show sensitivity towards various factors that are responsible for changes to water quality, and the entire biomonitoring activities have appeared to very much cost-effective than physicochemical analysis [3][4]. In India, a limited number of studies have been carried out on the ecological aspects of aquatic entomofauna [5][6]. Being non-biodegradable, heavy metals undergo a global ecological cycle [7]. The heavy metal lead (Pb) has been established

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to be highly toxic to plants and animals [8] whereas mercury (Hg) has exhibited considerable harmful effects on protein metabolism and functioning of the reproductive systems of aquatic insects including *Laccotrephesruber*[9].

Rapid industrialization is associated with environmental degradation caused by the discharge of toxic chemicals along with the heavy metals that enter into the air, water and soil [10]. Even if they are present in low and undetectable quantities, their recalcitrance and consequent persistence in the environment exhibit toxic effects through natural ecobiological processes such as biomagnification, bioconcentrations and bioaccumulation [11].Water contaminated with industrial discharge contains appreciable amounts of toxic metals and in the long run, can affect the surrounding soils and elevate the concentration of toxic metals in soil [12].Aquatic organisms can accumulate heavy metals from various sources including sediments, soil erosion, air depositions of dust alongwith aerosol and discharge of wastewater [13].

2. Materials and Methods

2.1 Study Sites

Present study areas are situated at three different contrasting regions in the eastern India: (1) Station I:a large water impoundments encircled by hilly forests on all sides (Rissia Dam) as natural or control study site at Kuldiha Wildlife Sanctuary, in the state of Odisha(between 21° 20' to 21° 30' N and 86° 26' to 86° 45' E) [Fig 1(a)]; (2) Station II:a large water pond at Tamluk, Midnapore (East), in the state of West Bengal, India, which is used for the human uses and moderately polluted(between 22° 18′ 0″ N and 87° 55′ 12″ E) [Fig 1(b)]; and (3) Station III:water body at HPCL, Haldia, Midnapore (East), in the state of West Bengal – highly polluted industrial belt(between 22° 1' 46.1232" N and 88° 3' 34.035" E) [Fig 1(c)].

Fig 1: Selected three study sites: (a) Rissia Dam, Kuldiha WLS, Odisha (S –I); (b) Tamluk, WB (S-II) and (c) HPCL, Haldia, WB (S-III)

2.2 Collection of samples

Random samplings were done with the help of insect net from three different aquatic bodies.For sampling in the water column, the net was dredged through the bottom sediment to collect the sedentary and benthic macro-invertebrates for at least three times. The collected water, soil, aquatic plants and aquatic insects were brought to the laboratory. Soil samples were dried after removing unwanted materials, and aquatic plant samples were cleaned by fresh water and different specieswere then separated, counted and dried and different individuals of aquatic insect *Laccotrephesruber*were kept into specimen tubes containing 70% alcohol for the quantification of density and also for the subsequent analysis for heavy metal.

2.3 Analysis of physicochemical parameters

Physical parameters of water samples (temperature, pH, conductivity and Total Dissolved Solids - TDSof water) were recorded by PCSTestr 35 Multi-Parameter (Eutech PCSTEST35-01X441506 / Oakton 35425-10).

In order to analyse heavy metals from selected samples, Atomic Absorption Spectroscopy (AAS) was used in laboratory.

1) For water samples, test methods followed are: Lead (Pb): IS: 3025 (Part-47): 1994 Reaffirmed 2009;Mercury (Hg): IS: 3025 (Part-48): 1994 Reaffirmed 2009.

2) For soil samples, test methods followed are: Lead: APHA 23rd Edition 3111B; Mercury: APHA 23rd Edition 3112B.

3) For the aquatic plant and aquatic insect samples, those were digested using microwave assisted acid digestion according to USEPA 3051a [14].

2.4 Deduction of Bioaccumulation Factor (BAF)

Bioaccumulation is the net result of thechemical uptake process into an organism at the respiratory surface and from the diet and chemical elimination from the organism, including respiratory exchange, fecal egestion, and metabolic biotransformation of the parent compound and growth dilution. The competing uptake and elimination resulting in bioaccumulation can be represented mathematically by

$$dC_B / dt = (k_1 C_{WD} + k_D C_D) - (k_2 + k_E + k_M + k_G) C_B$$

where C_B is the chemical concentration in the organism (g.kg^{-1}), t is a unique time (d^{-1}), k_1 is the chemical uptake rate constant from the water at the respiratory surface (L.kg^{-1}.d^{-1}), C_{WD} is the freely dissolved chemical concentration in the water (g.L^{-1}), kD is the uptake rate constant for chemical in the diet (kg.kg^{-1}.d^{-1}), C_D is the chemical concentration in the diet (g.kg^{-1}), and k_2, k_E, $k_M$and k_G are rate constants (d^{-1}) representing chemical elimination from the organism via the respiratory surface, fecal egestion, metabolic biotransformation and growth dilution, respectively.The factor to which this process occurs, can be expressed as bioaccumulation factor (BAF), and at steady state ($dC_B / dt = 0$), the BAF can be calculated as

$$BAF = C_B / C_{WD}$$

The BAF is mainly measured under field conditions including the total chemical concentration in the water phase, i.e., BAF = C_B / C_{WT}, which is the ratio of the chemical concentration in an organism or biota to the concentration in water:

$$BAF = \frac{Concentration\ in\ organism\ (through\ diet\ \&\ total\ surfaces)}{Concentration\ in\ water}$$

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3. Results and Discussion

3.1 Study of water quality parameters:

In three different contrasting study sites, water qualities were measured with PCSTestr 35, which are pH, temperature, Total Dissolved Solids (TDS) and conductivity.

Table 1: Water Parameter recording from three study sites

Water Parameters	S - I	S - II	S - III
pH	7.0	8.15	7.06
Temperature (°C)	24.2	20.8	21
TDS (ppm)	42.2	350	649
Conductivity (µs/cm)	58.8	540	915

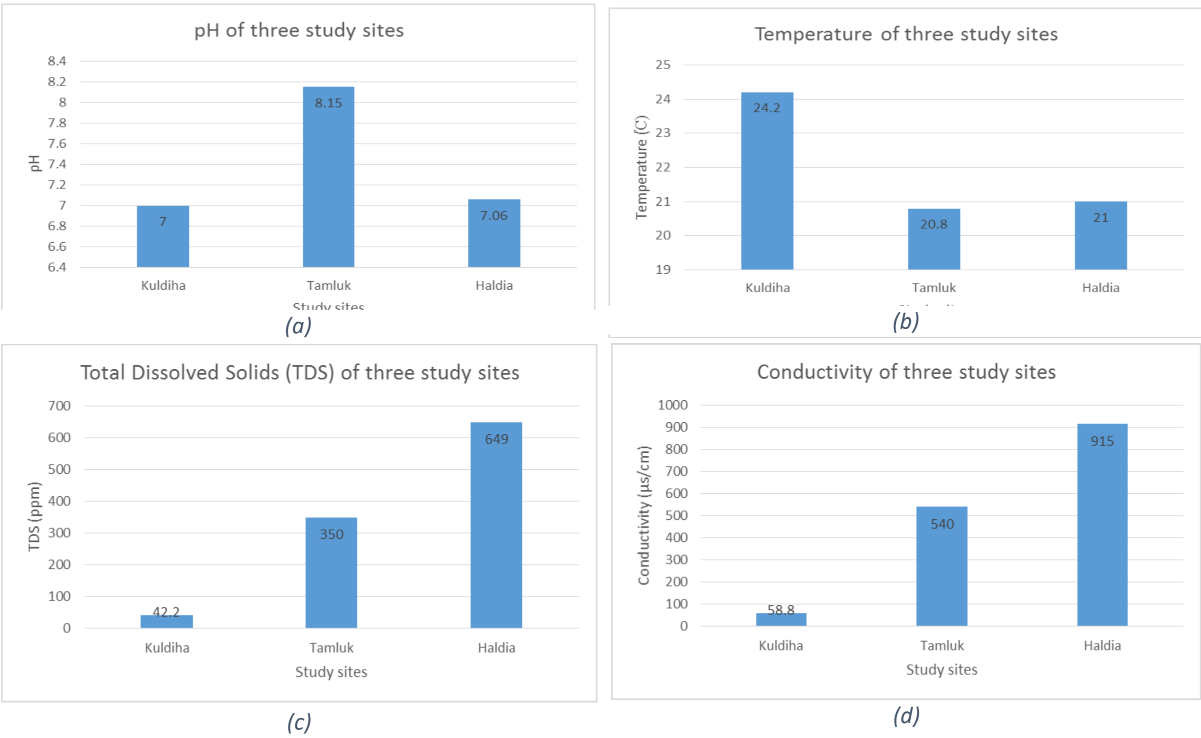

Fig 2: Water parameters of study sites: (a) pH, (b) Temperature, (c) TDS and (d) Conductivity

The study area's pH, temperature, TDS and conductivity are tabulated in Table 1 and Fig 2.ThepH of the study sites ranged from 7.0 to 8.15 and temperature were fluctuated from 20.8°C to 24.2°C.TDS of water is directly related to the conductivity of dissolved ionized solids in the water. In the municipal area (S - II), water with detergents, revealed an average TDS level. For the industrial area (S - III), cooling towers, power plants, and food processors can contribute to the high TDS level. From the above table, it is seen that TDS level is lower in S -I, moderate in S - II and higher S - III. Generally, human disturbance tends to increase the amount of dissolved solids entering waters, which results in increased conductivity – reflects

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in the Table 1 and Fig 2 (higher conductivity at industrial site, moderate at municipal site and lower in natural site).

3.2 Ecology of selected aquatic insect *Laccotrephesruber*

Laccotrephesruber commonly known as water scorpion belongs to family Nepidae of suborder Heteroptera of order Hemiptera is carnivorous, found almost all types of freshwater systems and is dominant and pollutant tolerant species. Though most of the time they live in water but sometimes emerge out of water on the ground or under stones in damp beds of recently dried streams. All legs help in swimming but they are not good swimmers. Fore legs are moved up and down and middle is used for kicking motion, each pair operates simultaneously as a unit. When crawling on objects under water, normal alterations of legs occur. Abdominal appendages thrust up to the surface as the insect crawls or move slowly. They feed on various types of small aquatic animals after capturing them with front raptorial legs. Water scorpions inflict painful bite when handled. Though they have well developed wings but they seldom fly. The body is broad, rather flattened and abdomen above is yellowish red in color; respiratory siphon at least 2/3 as long as body length, but usually as long as or somewhat longer than body; adults are generally 11 – 45 mm in total length; antennae 3-segmented, segment 2 with a fingerlike projection; lateral margins of pronotum slightly concave but not constricted at transverse groove; prosternum without sulci posterior of fore coxae; hemelytra smooth, membrane thin with distinct venation.

3.3 Heavy metal concentration study

Heavy metal (Pb and Hg) concentrations in water, soil, aquatic plants (1. *Marsilea* sp., 2. *Nymphaea* sp., 3. *Rotala*sp, 4. *Lemna* sp., 5. *Pistia* sp. and 6. *Commelina* sp.), and aquatic insect (Hemiptera: Heteroptera:*Laccotrephesruber*) were measured by AAS[1, 2, 3 were estimated for Kuldiha (S-I); 4, 5, 6 for Tamluk (S-II) and 2, 4, 5 for Haldia (S-III)- as werefound at the time of sampling] and are depicted in Fig 3 (S-I), Fig 4 (S-II) and Fig 5(S-III).

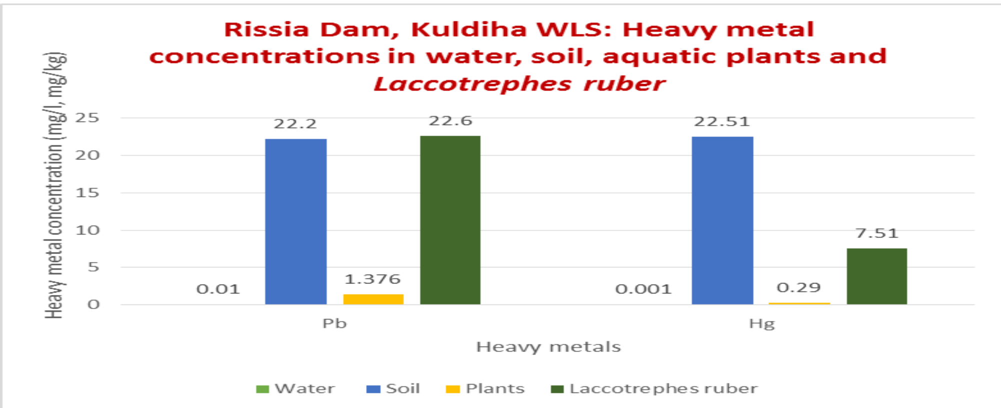

Fig 3: Heavy metal concentrations in water, soil, aquatic plants and Laccothrephesruber in S-I

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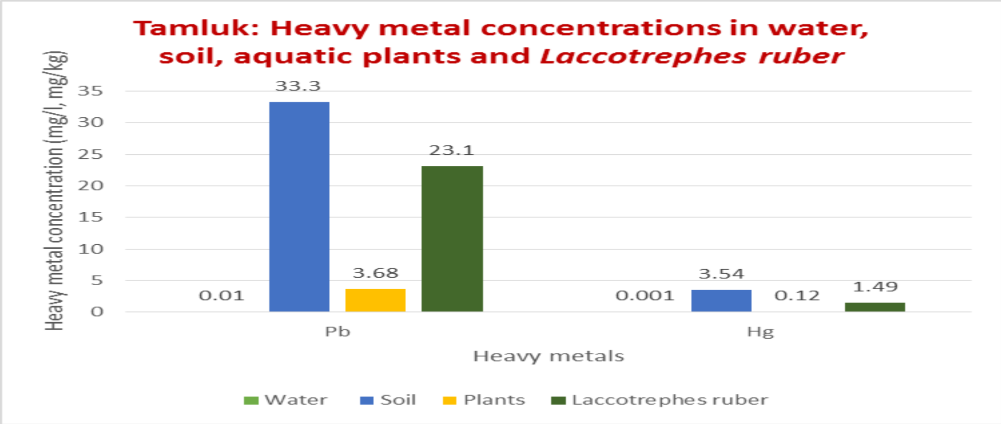

Fig 4: Heavy metal concentrations in water, soil, aquatic plants and Laccotrephesruber in S-II

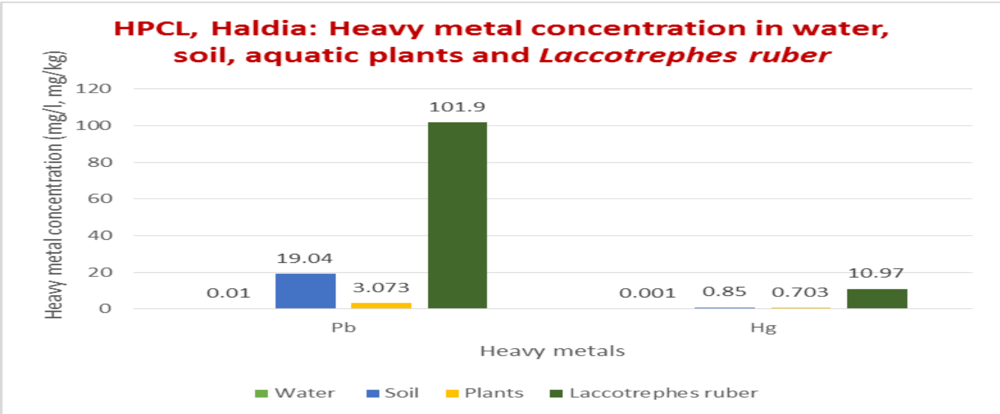

Fig 5:Heavy metal concentrations in water, soil, aquatic plants and Laccotrephesruber in S-III

The heavy metal concentrations for each study sites were measured and depicted in the following table (Table 2).

Fig 2: Water parameters of study sites: (a) pH, (b) Temperature, (c) TDS and (d) Conductivity

Sites	**Water**	**Soil**	**Aquatic plants**	***Laccotrephesruber***
S - I	Pb>Hg	Hg>Pb	Pb>Hg	Pb>Hg
S - II	Pb>Hg	Pb>Hg	Pb>Hg	Pb>Hg
S - III	Pb>Hg	Pb>Hg	Pb>Hg	Pb>Hg

3.4 Bioaccumulation Factor (BAF) analysis

Presently, there are no criteria for the reporting of BAF values. The most associated experimental factors that determine the quality of reported BAF data include the analytical rigor applied throughout the sampling and analytical process and the study's statistical design.

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There is enough information in the literature on environmental analysis criteria, including the usage of ‘blanks’ and reference materials, quality assurance and quality control (QA / QC) protocols, and criteria for good laboratory practice [15].

The gender, reproductive status, life-stage or age, size, lipid contents etc. of an organism can influence the BAF [16][17]. Organisms with higher lipid contents have a greater capacity to store hydrophobic organic chemicals and therefore, can exhibit a higher BAF. The trophic position is a crucial factor influencing the BAF observed for legacy pollutants [18]. For biochemical that magnify in the food web, the highest BAFs are observed in the highest trophic level species. Food web magnification factor studied in aquatic systems show that for chemicals that are not metabolized, the average increase in lipid normalized concentrations ranges between a factor of 2 and 6.5 for each trophic position [19].

It isn’t easy to compare BAFs from one food web to another because each ecosystem has unique characteristics, i.e., water column depth, dietary preference, primary production and organic matter, trophic structure, temperature and varying degrees of benthic interaction with the sediment [20][21]. Illustration and discussion of factors affecting the bioaccumulation and trophic transfer of persistent organic chemicals in arctic marine and freshwater food webs with an empirical data analysis was reported [22].

From the analysis of Bioaccumulation Factorof*Laccotrephesruber*, it is seen that– (i) in S-I, Hg is very bioaccumulative(77%) and Pb isless bioaccumulative (23%) [Fig 6(a)]; (ii) in S-II,Pb is moderatelybioaccumulative (61%)than Hg (39%) [Fig 6(b)]; and (iii) in S-III,Pb is very much bioaccumulative (90%) and Hg islessbioaccumulative (10%) [Fig 6(c)].

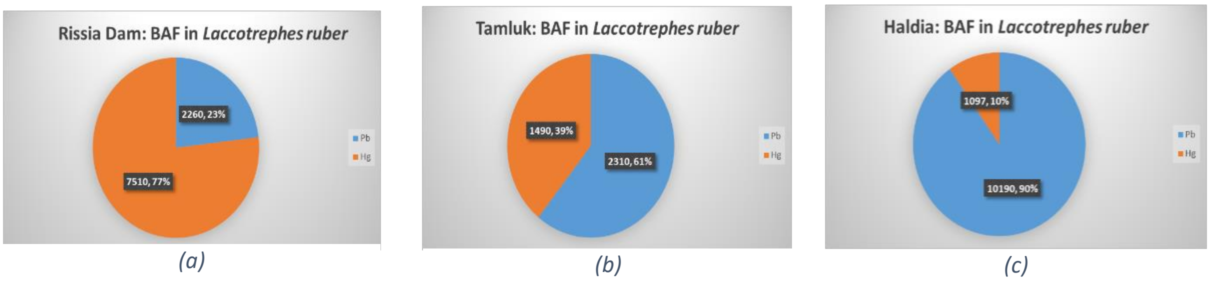

Fig 6:Bioaccumulation Factor in (a) S-I (b) S-II (c) S-III

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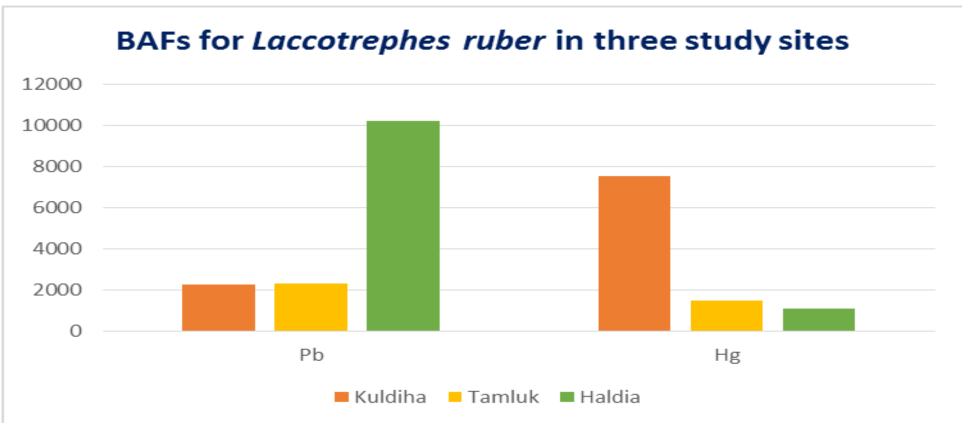

Fig 7: BAF values of Pb and Hg in Laccotrephesruber in three study sites

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Also it is concluded that – (i) BAF value of Pb is nearly same in S-I and S-II and much higher in S-III; and (ii) BAF value of Hg is nearly same in the S-II and S-III and much higher in S-I in the specified species *Laccotrephesruber*(Fig 7).

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Temporal stratification of weeds under System of Rice Intensification and conventional rice cultivation

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Abstract

A synecological studyon weeds was conducted to observe their temporal stratification and diversity in rice fields. The survey was performed across thephenophasesof rice (vegetative phase, reproductive phase, and mature phase.) to understand the crop-weed interaction. In this study, two cultural practices of rice cultivation, conventional and System of Rice Intensification (SRI) were considered. The weeds collected from the field were identified, and biomass, relative abundances were calculated. Also, diversity indices such as Simpson's Index, Shannon index andevennesswere computed. The ecosystem service generated from the weeds were documented.The study showed that the conventional plots were more diverse than the SRI plots. However, higher biomass for weed species was observed under SRI when compared to conventional plots. There were 24 dicotyledonous and 18 monocotyledonous weed species. From the abundance study,it was found that the SRI plots were more evenover the conventional plots. Thus, nutrient competition and sharing between the rice plants and weeds differ temporallyin SRI and conventional plots.The study suggests selective removal of weeds from the rice fields that will improve the crop yield as well as generate various ecosystem services.

Key words: Diversity indices; Phenophase; Rank-abundance; Stratification; Weed distribution

Introduction

Rice (*Oryza sativa* Linn.) is one of the essential food itemsof more than 50% people of the world and contributes about one-fifth to the total calorie consumption (Singh et al. 2012). Among several biotic components that influence the rice plant growth, weeds are the typical example.Weeds share the collective pool of available resource for their growth (Nyarko and Datta 1993; Pane et al. 2000).Most of the weed species exhibit uncontrolled exponential growth resulting in crop yield loss. Moreover, they affectgrain quality and quantity. According to Inamura et al. (2003), weed competes with rice for amount of nitrogen in grain and also affected the panicle number which results in reduced seed production per square meter.

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From the beginning of the crop cultivation, weed infestation has always been a significant problem for rice cultivation as it emerges when the rice seeds germinate (Kumalasari 2014).It causes nearly 80% crop yield loss if left uncontrolled (Cousens and Mortimer 1995). Globally, about 10% of the total yield is reduced by weeds (OerkeandDehne 2004), and in India, about 33% of rice yield losses are caused by weeds (Mukherjee 2004). Reports on secondary effectincludes reduction in harvest, processing efficiency, infestation of pest and production rate. The hierarchy of the crop-weed competition is influenced by the components like plantation time, species type and spatial arrangements (McDonald et al. 2009).In agricultural management, weed control is one of the vital challenges (Kumalasari 2014). Masum et al. (2019) identified the allelopathic indigenous rice (*Oryza sativa* L. ssp. *indica*) varieties from Bangladesh in the weed-infested rice fields and studied the extent of allelopathic interference relative to resource competition. They found that one of the indigenous variety -Boteswar, had weed-suppressing effect. Inamura et al.(2003) observed the increase of nitrogen content in rice on removal of weeds from the field plots. Besides, weed removal enhanced rice production by 10% in the rainfed area and around 17-19% in irrigated condition.

In general, studies have been made on crop-weed interaction (Kushwaha et al. 2018; Akter et al. 2018; Haris et al. 2019)and weed control issues and their adverse effects(Derksen et al. 2002; Wall 2007; Giller et al. 2009; Farooq et al. 2011; Rodenburg et al. 2019) but from the ecological point of view, there are onlya few papers that address the change in the community structure, diversity and ecosystem services generated from them. Temporal stratification is the gradual change of species composition of an area along the time axis. The change is transient and in coherence with the change in physical, chemical and biological environment. Thus, the study on weed community and their temporal stratification in rice fields under different cultivation types appears to be an essential issue of research.Ecosystem services are the paybacks contributed by the ecosystem to humankind (Costanza 1997). In the agricultural fields, weeds are naturally occurring species, which normally co-exist with the other target plants such as rice, weed or maize and interrupt in the growth and production of the target plants. The objective of the present research is to study theweed abundance, diversity indices and composition under two practices (Conventional and System of Rice intensification) at various growth stages; and delineate the ecosystem services generated from weeds.

Materials and methods

The study was conducted in the Crop Research and Seed Multiplication Farm, The University of Burdwan, West Bengal ($23^0$14'26" N and $87^0$52'09" E), India.The experimental plots of rice fields were framedfor the variety IET-4786. Two methods of cultivation (conventional and SRI) were implemented for rice cultivation. Sampling of weeds were done following quadrat method. In each field plot of rice, 10 quadrats of size 1m × 1m were framed under the conventional and SRI cultivation. In total, 30 quadrats each from conventional and SRI field plots were surveyed. The weed samples were identified following Caton et al. (2010).The samples were oven-dried at 80^oC, and corresponding dry weight was taken.The biodiversity indices of the weed species were calculated in the three phenophases of rice plant viz. vegetative phase,reproductive phase and maturephase.

Braun-Blanquet method was applied for the assessment of weed cover of an area. The method describes the abundance and species density of a large-scale area (Kamoshita et al. 2014). A scale of 0-5 was used that denoted the number of species present in the quadrate and covered by any weed species (0 means taxa is absent in this quadrat and 5 means taxa is present abundantly and covered 75% area of the quadrat). The dominance value was converted into mean cover classes.

The biodiversity indices like dominance, Simpson, Shanonand evenness indices were studied following Krebs (2009). The indices were calculated in Past software version 3. Cluster analysis was performed following UPGMA and Bray-Kurtis similarity for weed community. The ecosystem services of the weed species found in the rice fields were identified from local survey.

Results and discussion

Results showed that there were 42 species of weed under 22 families and thirty species of weed under twenty families in SRI and conventional practices,respectively. Among the 42 species, there were 24 dicotyledonous and 18 monocotyledonous identified from the field. In both the practices,Poaceaewas the dominant family followed by Cyperaceae. In the SRI, 7weed species of family Poaceaewere noted, and 6 species of the same family was observed under conventional practice.

Temporally, there was a little variation in the species number or taxa in the conventional practice. During the vegetative phase of rice, there were only 30 weed species, and at the maturephase of rice, the number came down to 28. The two species, *Pistia stratiotes* and *Polygonum* sp. were absent at the maturephase of rice. The relative abundance varied across the growth phases of rice cultivation (Table 2).

However, there were 36 weed species observed throughout the study in the SRI plots. At the start, there were 33 weed species at vegetative phase except *Oryza rufipogon*, *Polygonum* sp. and *Sphenocleazeylanica*. At reproductive phase, the above three species appeared, but the *Hygrophiladifformis* disappeared. Therefore, the species richness increased to 35 in the SRI field plots. At mature phase, the species richness decreased to 33 with the disappearance of *Heliotropium indicum*, *Mimosa pudica* and *Numphoides indica*. It was noted that the species *Hygrophiladifformis* re-appeared in the mature phase of rice. In the SRI practice,*Cyperus difformis*wasabundant in the reproductive and mature phase, whereas *Cyperus iria*was more in number during the vegetative growth phase of rice (e.g. Table 1). The evenness index varied between 0.79 and 85 along thegrowth phases

Moreover, in the conventional practice, *Fimbristylismiliacea* of Cyperaceae family was abundant in the vegetative phase and *Echinocholacolona* of Poaceae was higher in number at reproductive phase of rice plants. It was found that *Monochoria vaginalis* of Pontederiaceae family was relatively abundant at the mature stage of the SRI cultivation. The evenness index varied between 0.80 and 0.82 in the sampling plots of conventional fields. The distribution of weed species is shown in the Venn diagram (Fig. 1).

The dominance index values at the vegetative, reproductive and mature phases under conventional and SRI field plots were low and showed no significant difference ($p < 0.05$). In contrast, the

Simpson index values were high and closed to 1. The Shanon (H) index values of diversity are higher in all the growth phases of SRI in comparison to conventional plots (e.g. Table 1).

Table 1 Table showing the diversity indices of the weed community under conventional and SRI practices

	Conventional			SRI		
Diversity Indices	Vegetative phase	Reproductive phase	Mature Phase	Vegetative Phase	Reproductive Phase	Mature Phase
Weed species	30	30	28	33	35	33
Individuals	372	360	387	432	439	385
Dominance	0.04	0.04	0.04	0.04	0.04	0.04
Simpson index	0.96	0.96	0.95	0.96	0.96	0.96
Shannon index	3.18	3.18	3.13	3.34	3.34	3.26
Evenness index	0.80	0.80	0.82	0.85	0.81	0.79

In order to evaluate the similarity between the weed community at vegetative, reproductive and mature phases, cluster analysis was performed (Fig. 2a, 2b,2c).At the vegetative phase of rice, there was six major clusters with more than 60% similarity(Fig.2a). Five pairs of weed species that exhibited similar relative abundancesnear to 1 such as *Hemigraphishirta - Lindernia ciliate, Ageratum conyzoides - Limnophila heterophylla, Dentella repens - Aeschynomene indica, Heliotropium indicum - Lindernia parviflora, and Cassia tora - Oryza rufipogon*. The co-existence of rice plants along with the weed species showed nutrient partitioning among the species. The weed species followed random distribution within each field plots, and this happened due to even distribution of soil nutrient in the plots. However, there was variations in the cluster forming weed species during the reproductive phase and mature phase of rice plants. During the panicle initiation and flowering stage of rice growth, there were six significant clusters with more than 70% similarity (Fig. 2b). There exist three pairs of weed species that formed the clusters with similarity percentage near to 100 such as *Hemigraphishirta - Xanthium strumarium, Limnophila heterophylla-Lindernia ciliate and Dentella repens - Phyla nodiflora*. At the mature phase or ripening of rice plants, the cluster formation among the weed species changed again. There were seven significant clusters, where four paired weed species had similar relative abundance, nearly 100% such as *Limnophila heterophylla-Xanthium strumarium, Hemigraphishirta-Polygonum sp., Commelinabenghalensis- Justicia simplex and Echinochloacruss-galli-Lemna sp*. (Fig. 2c).

The present study showed that the relative abundances of most of the weed species in the conventional field increased temporally. However, in the SRI field plots, there were only 6 species among the 36 weed species such as *Euphorbia hirta*, *Fimbristylismiliacea*, *Justicia simplex*, *Panicum repens*, *Polygonum* sp. and *Solanum nigrum*, showed gradual decrease in number temporally. The weed species diversity was more in the SRI than the conventional, but over time, the basal area covered by the rice plants in the SRI fields was observed to be more as there were

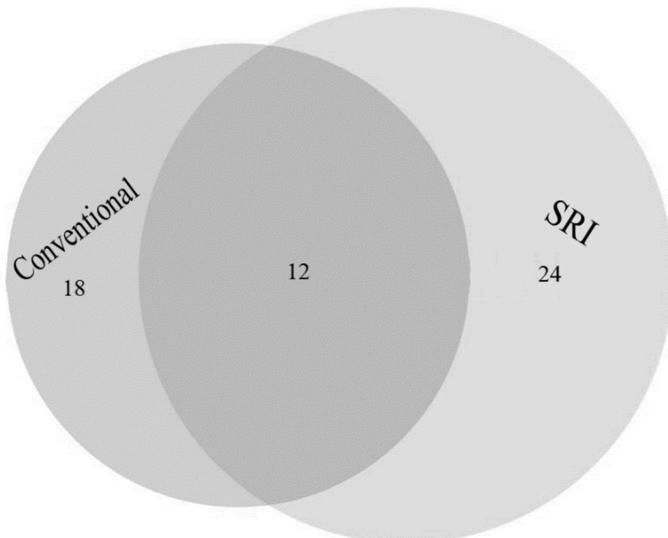

Fig 1. Venn -diagram showing the distribution of weed species between conventional and SRI practices. The digits represent the number of taxa or weed species found in conventional and SRI field plots. The intersection represents the common weed species

more tiller numbers and this prohibited the distribution of weed species in the field plots.In the conventional field plots, *Cyperus iria* was the most abundant at vegetative phase of rice, whereas *Cyperus difformis* was found to be abundant at reproductive and mature phases. However, the SRI field plots, weed species such as *Fimbristylismiliacea* was abundant at vegetative phase of rice plants. This was followed by *Echinochloacolona* at reproductive phase and *Monochoria vaginalis* at mature phase. The present outcome are in agreement with the research findings by Consenco et al. (2018).

Jordan (1993) defined crop competitiveness as a complex character that involves the ability of the rice plants to sustain yields despite the presence of weeds and the ability to suppress weed growth. In a field of the conventional and SRI, common weeds species appeared coincidently. Similar environmental resources such as water, light, nutrients and CO_2 (at different levels) are required by rice plants and weed community, thus competition occurs and affects the productivity of rice crop.In the present study, both the SRI and conventional field plots were greatly affected in terms of yield.

Fried et al. (2008) found that the most crucial factor determining weed community structures was the cropping system. The organic and inorganic base of SRI field plots had distinguished effect on weed community when compared to chemical (NPK) base of conventional practice. Moreover, water retention in the conventional field plots and intermittent wetting and drying conditions had crucial role in the growth of weed species. Kabaki and Nakamura (1984) reported that *Monochoria vaginalis* tends to be abundant in paddy fields atlow temperatures and low levels of fertilizer application. In contrast, *Echinochloacolona* tend to be abundant at high fertilizer levels. The present study was done at Rabi season with the mean air temperature ranged between 16^{o}C and 30^{o}C. In the SRI field plots, the intermittent wetting and drying conditions and temperature favoured the growth of *Monochoria vaginalis* during the mature phase of rice. Fertilizer application was done before panicle initiation at the SRI as well as conventional field plots that favoured the growth of *Echinochloacolona* along the reproductive phase of rice. The presence of *Cyperus iria*and *Cyperus difformis*had negative effect on rice yield. Hosoya and Sugiyama (2017) reported that the species of the family Cyperaceae are perennial, which enables their propagation in the soil, by vegetative organs such as rhizomes and tubers and possess serious threat to rice yield if not checked through herbicides.

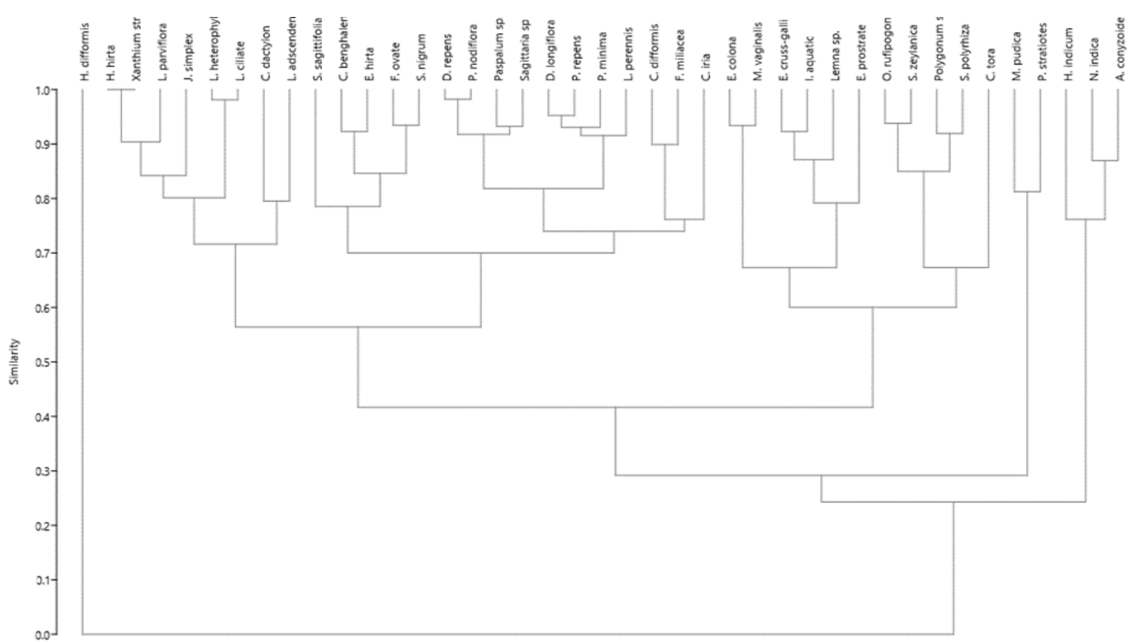

Fig. 2a Vegetative phase

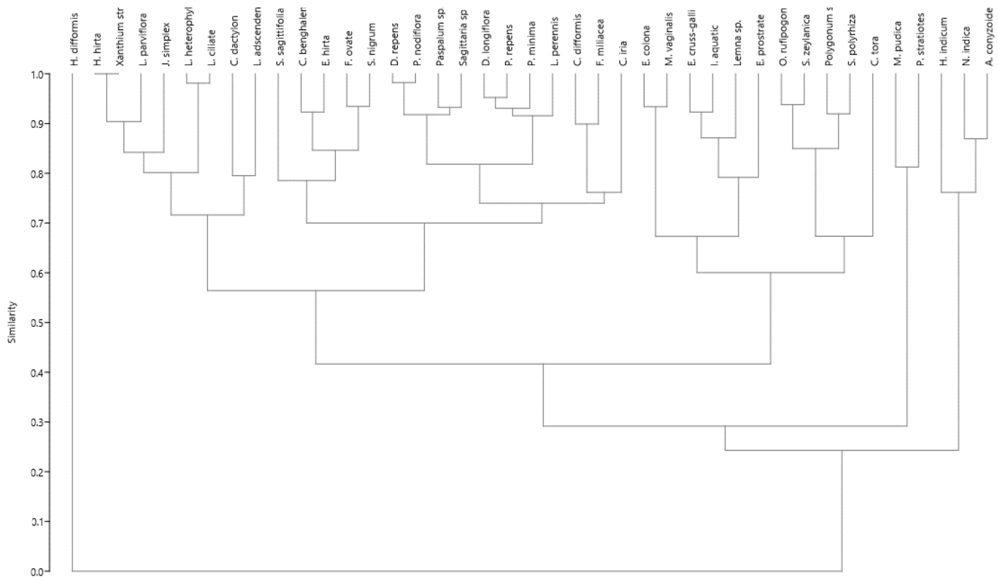

Fig. 2b Reproductive phase

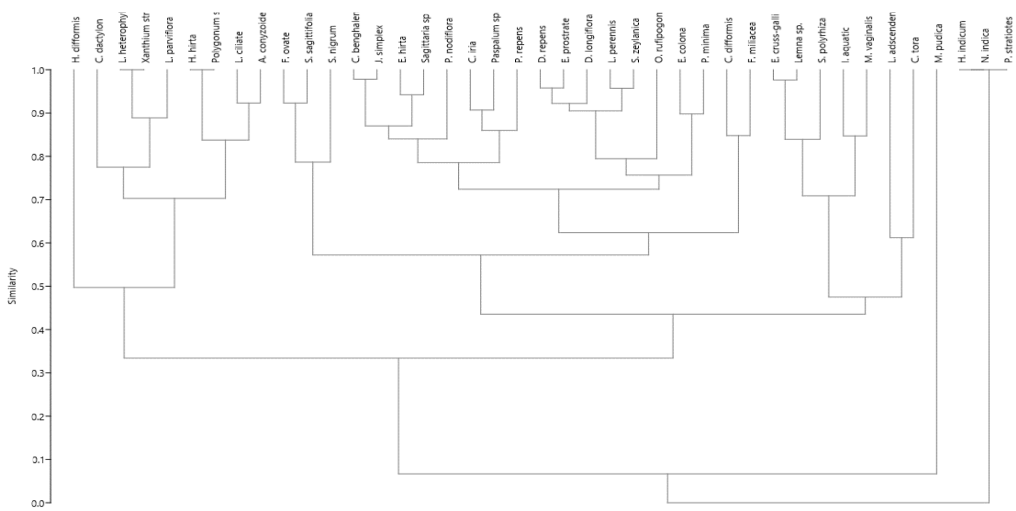

Fig. 2c Mature phase

Besides the negative impacts of weed species, there exists different ecosystem services that can be considered as by-product in addition to rice yield. Though the weeds grow naturally, if removed selectively from the rice fields, will benefit mankind in different directions. The ecosystem

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services generated from the weed species are summarized in Table 3. The present research strongly supports the removal of weeds from the rice fields, but not through herbicides or chemical treatment but by mechanical weeding techniques.

Table 2 Relative abundance (RA) of weed species under different family at vegetative (V), reproductive (R) and mature phases (M) in the conventional and SRI practices. The weed species have either annual (A) or perineal (P) life cycle

Species	**Family**	**Flowering Class** Dicot (D)/ Monocot (M)	**Life Cycle**	**Conventional**			**SRI**		
				Relative Abundance					
				(V)	**(R)**	**(M)**	**(V)**	**(R)**	**(M)**
Aeschynomeneindica	Fabaceae	D	A	0.19	0.3	0.66	-	-	-
Ageratum conyzoides	Asteraceae	D	A	-	-	-	0.28	0.13	0.2 1
Cassia tora	Caesalpiniaceae	D	A	0.14	0.25	0.15	-	-	-
Commelinabenghalensis	Commelinaceae	M	P	0.17	0.2	0.28	0.25	0.5	0.42
Cynodondactylon	Poaceae	M	P	0.28	0.1	0.09	0.47	0.23	0.15
Cyperusdifformis	Cyperaccae	M	A	0.44	0.7	0.53	0.84	1	1
Cyperusiria	Cyperaceae	M	A	0.5	0.2	0.28	1	0.97	0.76
Dentellarepens	Rubiaceae	D	A	0.19	0.27	0.38	0.625	0.57	0.33
Digitarialongiflora	Poaceae	M	A	0.33	0.5	0.5	0.47	0.6	0.33
Echinochloacolona	Poaceae	M	A	0.86	1	0.72	0.38	0.37	0.36
Echinochloacruss-galli	Poaceae	M	A	0.42	0.6	0.59	-	-	-
Eclipta prostrate	Asteraceae	D	P	0.47	0.6	0.41	0.5	0.23	0.3
Euphorbia hirta	Euphorbiaceae	D	A	0.22	0.1	0.18	0.34	0.5	0.52
Fimbristylismiliacea	Cypcraceae	M	A	1	0.8	0.93	0.38	0.77	0.89
Fimbristylis ovate	Cyperaceae	M	A	-	-	-	0.56	0.5	0.42
Heliotropiumindicum	Boraginaceae	D	A	-	-	-	0.19	0.07	0
Hemigraphishirta	Acanthaceae	D	A	-	-	-	0.47	0.4	0.27
Hygrophiladifformis	Acanthaceae	D	A	-	-	-	0.16	0	0.06
Ipomoea aquatic	Convolvulaceae	D	P	0.61	0.7	0.845	-	-	-
Justicia simplex	Acanthaceae	D	A	0.16	0.1	0.28	0.21	0.37	0.39
Lemna sp.	Lemnaceae	M	P	0.31	0.5	0.5625	-	-	-
Limnophilaheterophylla	Scrophulariacea e	D	P	-	-	-	0.28	0.27	0.12
Lindernia ciliate	Scrophulariacea e	D	A	-	-	-	0.46	0.26	0.18
Lindernia parviflora	Scrophulariacea e	D	A	-	-	-	0.19	0.33	0.15
Ludwigiaadscendens	Onagraceae	D	A	0.14	0.2	0.28	0.28	0.3	0.06
Ludwigia perennis	Onagraceae	D	A	0.19	0.4	0.46	0.66	0.5	0.27
Mimosa pudica	Onagraceae	D	P	0.16	0.13	0.03	0.18	0.06	0

Monochoria vaginalis	Pontederiaceae	M	A	0.67	0.9	1	0.1875	0.3	0.15
Nymphoidesindica	Menyanthaceae	D	P	-	-	-	0.13	0.1	0
Oryza rufipogon	Poaceae	M	A	0.14	0.4	0.25	0	0.2	0.24
Panicum repens	Poaceae	D	P	0.14	0.5	0.44	0.25	0.5	0.55
Paspalum sp.	Poaceae	M	A	0.16	0.3	0.3125	0.41	0.73	0.61
Phyla nodiflora	Verbenaceae	D	P	0.39	0.27	0.13	0.53	0.6	0.36
Physalia minima	Solanaceae	M	A	0.53	0.6	0.65	0.56	0.5	0.52
Pistia stratiotes	Araceae	M	P	0.22	0.13	0	-	-	-
Polygonum sp.	Polygonaceae	D	A	0.36	0.3	0	0	0.1	0.27
Sagittariasagittifolia	Alismataceae	M	A	-	-	-	0.75	0.73	0.36
Sagittariasp	Alismataceae	M	A	0.11	0.23	0.1875	0.56	0.67	0.45
Solanum nigrum	Solanaceae	D	P	-	-	-	0.34	0.57	0.6
Sphenocleazeylanica	Campanulaceae	D	A	0.44	0.4	0.46	0	0.13	0.21
Spirodelapolyrhiza	Lemnaceae	M	P	0.11	0.3	0.46	0.21	0.17	0.06
Xanthium strumarium	Asteraceae	D	A	0	-	-	0.375	0.4	0.12

Table 3 The ecosystem services generated by the weed species found in the rice fields of West Bengal, India

Species	**Ecosystem Services or uses**
Aeschynomeneindica	Edible, medicinal, agroforestry
Ageratum conyzoides	Edible, medicinal, cosmetics
Cassia tora	Medicinal
Commelinabenghalensis	Edible, medicinal, used in the preparation of dye.
Cynodondactylon	Medicinal
Cyperusdifformis	Not known
Cyperusiria	Edible, medicinal
Dentellarepens	Medicinal
Digitarialongiflora	Edible, beverage
Echinochloacolona	Edible, Fodder, Medicinal
Echinochloacruss-galli	Edible, medicinal, agroforestry
Eclipta prostrate	Edible, medicinal, cosmetics
Euphorbia hirta	Medicinal, pharmacological activities
Fimbristylismiliacea	Medicinal
Fimbristylis ovate	Medicinal
Heliotropiumindicum	Edible, medicinal
Hemigraphishirta	Medicinal
Hygrophiladifformis	Medicinal

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Ipomoea aquatic	Edible, medicinal
Justicia simplex	Medicinal, tradition uses
Lemna sp.	Fish feed, fodder
Limnophilaheterophylla	Antimicrobial activity
Lindernia ciliate	Medicinal
Lindernia parviflora	Medicinal
Ludwigiaadscendens	Edible, medicinal
Ludwigia perennis	Edible
Mimosa pudica	Edible, medicinal, agroforestry
Monochoria vaginalis	Edible, medicinal
Nymphoidesindica	Medicinal
Oryza rufipogon	Edible, medicinal
Panicum repens	Agroforestry
Paspalum sp.	Not known
Phyla nodiflora	Edible, medicinal, agroforestry
Physalia minima	Fruits edible, medicinal
Pistia stratiotes	Fodder, ornamental, medicinal properties
Polygonum sp.	Not known
Sagittariasagittifolia	Edible, medicinal
Sagittariasp	Not known
Solanum nigrum	Edible, medicinal
Sphenocleazeylanica	Not known
Spirodelapolyrhiza	Green manure
Xanthium strumarium	Medicinal

Conclusions

The study focuses on the synecological aspect of weeds. The temporal stratification of the weed species in the rice fields were captured under the SRI and conventional cultivation practices. It was observed that the occurrence or abundance of weed species vary along the phenophases of rice and attributed to the factors such as water, light, temperature, CO_2 and nutrient conditions. Similar soil conditionsfavour different species of weeds, and the co-existence of rice plants along with the weed species showed nutrient partitioning among the species. The weeds have higher competitive ability than the crop; however, this effect could be caused by the higher weed densities.

The naturally occurring weed species, after removal can be channelized for many revenue generation purposes as these species are associated with edible, medicinal and cosmetic uses.

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Conflicts of interest

No conflicts of interest have been declared.

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Herd Immunity: A Success or a Failure

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Abstract

Amidst the COVID-19 pandemic, the most debated scientific topic has been Herd Immunity. It may be defined as a situation in which a major portion of a population (about 60 - 90%) develops some form of the disease and, therefore, becomes resistant to it. However, with such large number of cases, the healthcare facilities are bound to get overloaded. Some patients with severe cases of COVID-19 will be required to get admitted into the ICU (intensive care units) – which have limited beds. This could lead to more preventable deaths. Herd immunity has both positive and negative aspects. For instance, if we fail in the halfway for example in the country Sweden, then it will result in more deaths rather than decreasing the spread of infection. According to several theoretical modelling that people have conducted across the world and also in India suggest that there could be few waves of COVID-19 and people need to be prepared for them. In this review we are trying to assess whether herd immunity is a success or a failure.

Keywords Vaccine, Covid-19, Herd, Immunity, Population, Infection

Introduction

During this never-ending lockdown and the downfall in economy due to unemployment the most debatable approach by the scientists has been that we continue to live in lockdown and that everything will become normal as we approach herd immunity. Herd immunity is basically a technique to eradicate a disease or infection in which a population is made immune to a disease or an infection by vaccination or by exposing them to the disease or the infection and letting their own body develop an immunity against that disease or infection. Now, this strategy of exposing people to the disease can backfire too because aged people or people with a weak immune system can lose their lives while their body is still trying to create the necessary antibodies[1].

On the vaccine development front, according to studies or researches, three ways are being adopted. The first one is the immune boosting vaccine that improves the host's immunity. The second one is the monoclonal antibody for which CSIR has funded a collaborative programme between NCCS (National Centre for Cell Science) Pune, IIT Indore and Bharat Biotech. Third one is convalescent plasma therapy which can be life threatening. After all these researches and trials there still persists a question, "can COVID-19 be contained or stopped by herd immunity?"

Coronaviruses are a large family of viruses that are actually common throughout the world and can cause respiratory illness in people. There are several known coronaviruses that caninfect

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people and usually cause mild respiratory diseases, such as the common cold. However, at least two previously identified coronaviruses have caused severe illness — Severe Acute Respiratory Syndrome (SARS) coronavirus and Middle East Respiratory Syndrome (MERS) coronavirus.

The difference between COVID-19 from other viruses

While coronaviruses are common, coronavirus (COVID-19) is a new strain of coronavirus that had previously not been identified in humans. The key features of COVID-19 are respiratory symptoms with fever and cough. Like all new infections, understanding COVID-19 is important and challenging. The CDC is proactively monitoring the virus and taking measures like providing guidance for health care workers and issuing travel recommendations [2]

Herd immunity:

Acquired immunity is established at the level of the individual, either through natural infection with a pathogen or through immunization with a vaccine. Herd immunity stems from the effects of individual immunity scaled to the level of the population. It refers to the indirect protection from infection conferred to susceptible individuals when a sufficiently large proportion of immune individuals exist in a population. This population level effect is often considered in the context of vaccination programs, which aim to establish herd immunity so that those who cannot be vaccinated, including the very young and immune compromised, are still protected against disease. Depending on the prevalence of existing immunity to a pathogen in a population, the introduction of an infected individual will lead to different outcomes (Fig 1). [3,4,5]

In a completely naive population, a pathogen will propagate through susceptible hosts in an unchecked manner following effective exposure of susceptible hosts to infected individuals. However, if a fraction of the population has immunity to that same pathogen, the likelihood of an effective contact between infected and susceptible hosts is reduced, since many hosts are immune and, therefore, cannot transmit the pathogen. If the fraction of susceptible individuals in a population is too few, then the pathogen cannot successfully spread, and its prevalence will decline. The point at which the proportion of susceptible individuals falls below the threshold needed for transmission is known as the herd immunity threshold (Anderson and May, 1985). Above this level of immunity, herd immunity begins to take effect, and susceptible individuals benefit from indirect protection from infection [6,7]

How can we achieve herd immunity for an infectious disease

For infections without a vaccine where many people have developed the immunity against the disease because of prior infection or good immunization from the disease. The disease can still circulate among aged people, children below 10 years of age and persons with weak immune systems. Therefore, it is clear that herd immunity can be achieved by mass vaccination of the population or by exposing the people to the disease and letting their bodies develop immunity on their own.

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Positive side of Herd immunity:

If a high enough proportion of individuals in a population are immune, the majority will protect the few susceptible people because the pathogen is less likely to find a susceptible person. The important part is that it is cost effective.[8]

Negative side of Herd immunity:

All of this sounds rosy, but the problem with herd immunity is that it really hinges on vaccination. Without a vaccine, the only way to become immune to a disease is to contract it and live through it, which makes the strategy a whole lot more fatal. Even then, herd immunity has not been able to prevent outbreaks of measles or rubella in communities with immunization levels as high as 85% to 90% [9,10,11]

If we pursue herd immunity, the best-case scenario has between 43,000 and 100,000 people in Australia dying. To see how much fatal herd immunity can be, let’s look at the numbers. Our initial estimates put the herd immunity threshold for Covid-19 – the proportion of people who need to be immune for the disease to stop spreading – at 60-70% of the population. So a minimum of 60-70% of people need to be infected with Covid-19 for herd immunity to come into play, although new data from the CDC indicates that the number may be as high as 85%. It is important to note that one can’t really pick and choose these people, because unless you reach that threshold in every part of the country, you’ll still see disease outbreaks. The idea that we can only infect young people is simply outlandish, firstly because that’s not how society functions, and also because it’ll create groups of people with low immunity where the disease can still spread. [9]

In Australia, that would mean roughly 15-17 million coronavirus infections. Now, we also have a very good idea of the death rate from this disease – while the case-fatality rate is quite high, the true infection-fatality rate given a healthcare system that is not overwhelmed is likely to be around 0.3-0.6%.

Is Herd Immunity just a myth

The people who have developed immunity to the virus are very unlikely to become ill due to the same virus again, thus, the virus loses its transmissibility at the point when enough number of people in a specific area have developed the immunity. The problem lies in the fact that we are not aware of exactly how many people should get infected by the virus for the society to develop Herd immunity against COVID – 19. The key feature here is immunity. Production of Antibodies, which are the shield against a virus, are aided by medicines. Vaccines which produce army of antibodies are not yet developed against COVID 19. Thus, this two deficiencies have accelerated the spread of the concept around Herd immunity. There is another problem with herd immunity: the problem of herd [12] A person's herd changes with relocation, migration, or even tourist travel, new circle of friends--this is capable of breaching herd immunity.

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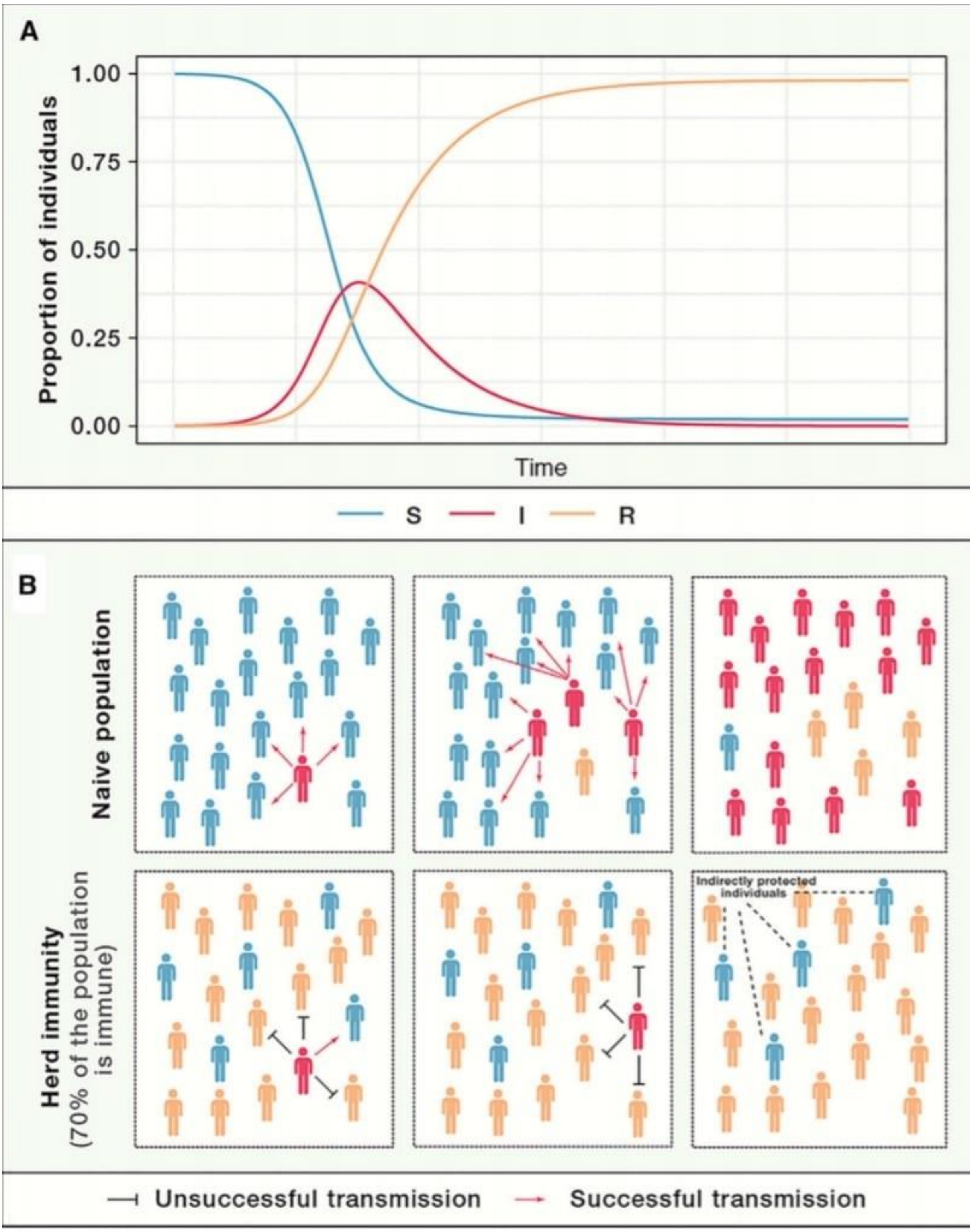
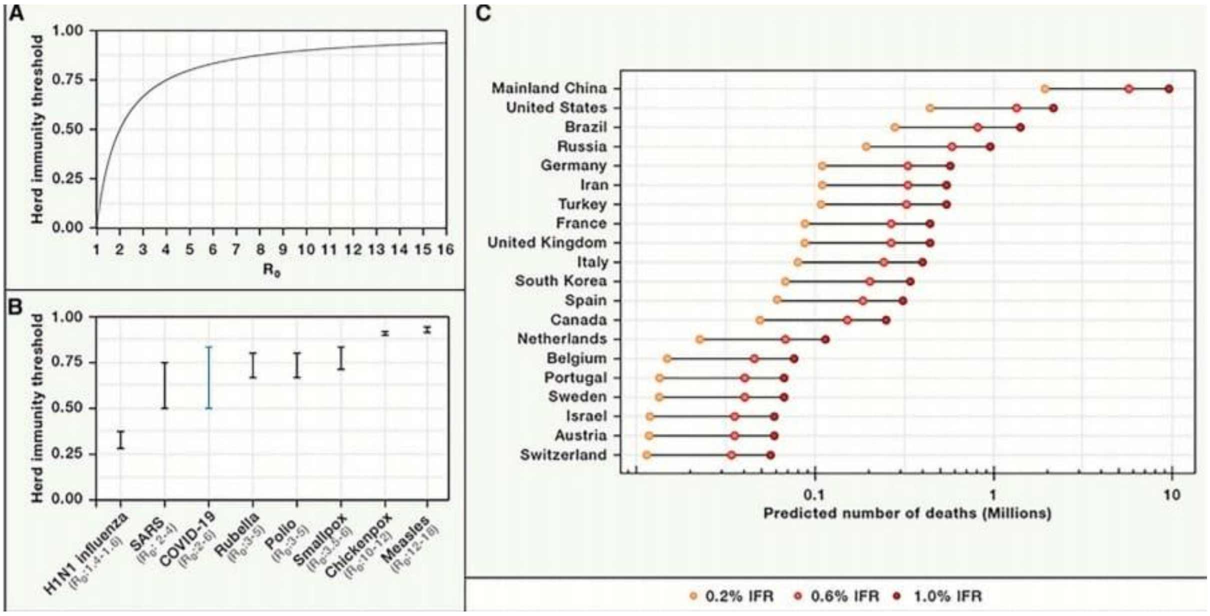


Adapted from 'Herd Immunity: Understanding COVID-19;' Haley E. Randolph1 and Luis B. Barreiro: Immunity 52, May 19, 2020

Figure 1. Herd Immunity (A) SIR (susceptible, infectious, recovered) model for a completely immunizing infection with an R0 = 4. The model assumes a closed population in which no people leave and no new cases are introduced. Following the introduction of a single infected individual, the proportion of infected in-dividuals (red line) increases rapidly until reachingits peak, which corresponds to the herd immunity threshold. After this point, newly infected in-dividuals infect fewer than one susceptible indi-vidual, as a sufficient proportion of the populationhas become resistant, preventing further spread of the pathogen (orange line).

(B) Schematic depiction of the disease propagation dynamics when one infected individual is introduced into a completely susceptible population (top panel) versus a situation in which an infected individual is introduced into a population that has reached the herd immunity threshold (bottom panel). In the naive population, an outbreak quickly emerges, whereas under the scenario of herd immunity, the virus fails to spread and persist in the population.

[3]



Adapted from 'Herd Immunity: Understanding COVID-19;' Haley E. Randolph1 and Luis B. Barreiro: Immunity 52, May 19, 2020

Figure 2. The Potential Health Burden of COVID-19 if Herd Immunity Is Achieved in the Absence of Vaccination

(A) Relationship between R0—the basic reproduction number (Box 1)—and the herd immunity threshold, which corresponds to the proportion of individuals in the population that would need be become immune for herd immunity to be established (y axis). As R0 increases, the proportion of the population that must be immune to generate herd immunity increases (1 – 1/R0).

(B) Basic reproduction numbers (R0) and the corresponding herd immunity thresholds for various infectious diseases. R0 estimates represent the commonly accepted R0 range for each of the pathogens reported.

(C) Expected number of absolute deaths for the top 20 countries with the highest incidence of COVID-19 as of April 10, 2020, assuming herd immunity is es-established at a uniform threshold of 67% (R0 = 3) in each country. Overall COVID-19 infection fatality rates (IFR) of 0.2%, 0.6%, and 1.0% are considered. We notethat these numbers are necessarily underestimates given that, even after the herd immunity threshold is reached, it will take a long time until there are no morenew cases, and therefore, no new deaths.

Concept of Herd Immunity

Under the simplest model, the herd immunity threshold depends on a single parameter known as R0, or the basic reproduction number. R0 refers to the average number of secondary infections caused by a single infectious individual introduced into a completely susceptible population [1,4]. If we consider a hypothetical pathogen with an R0 of 4, this means that, on average, one infected host will infect four others during the infectious period, assuming no immunity exists in the population. Mathematically, the herd immunity threshold is defined by 1 – 1/R0 (e.g., if R0 = 4, the corresponding herd immunity threshold is 0.75) (Anderson and May, 1985). Therefore, the more communicable a pathogen, the greater its associated R0 and the greater the proportion of the population that must be immune to block sustained transmission.

A similar parameter important for understanding population-level immunity is the effective reproduction number (Re or Rt). Re is defined as the average number of secondary cases generated by a single index case over an infectious period in a partially immune population (Delamater et al., 2019). Unlike R0, Re does not assume a completely susceptible populationand, consequently, will vary depending on a population's current immune state, which will change dynamically as an outbreak event or vaccination campaign unfolds. Ultimately, the goal of vaccination programs is to bring the value of Re below 1. This occurs when the proportion of the population with immunity exceeds the herd immunity threshold. At this point, pathogen spread cannot be maintained, so there is a decline in the number of infected individuals within the population.

Cost benefit analysis of HERD immunity:

It accounts for cost benefit analysis of vaccination program. It produces an extra benefit of disease reduction that could not have occurred if no HERD immunity had been generated in that specific area. Thus, it results in favourable cost effectiveness and cost benefit ratios.

When serotype replacement is accounted for, it reduces the predicted benefits of vaccination.[13,15]

So, it can be inferred that the incidence of the disease may decrease to a level beyond what was predicted from direct protection pointing to the fact that HERD immunity contributed to the reduction.

CONCLUSION:-

In spite of the knowledge of Herd immunity, efforts to control and eliminate measles were unsuccessful until mass vaccination using the measles vaccine began in the 1960s. Mass vaccination, discussions of disease eradication, and cost–benefit analysis of vaccination subsequently prompted more widespread use of the term herd immunity.

Since the adoption of mass and ring vaccination, complexities and challenges to herd immunity have arisen. Modelling of the spread of infectious disease originally made a number of assumptions, namely that entire populations are susceptible and well-mixed, which do not exist in reality, so more precise equations have been developed. In recent decades, it has been recognized that the dominant strain of a microorganism in circulation may change due to herd immunity, either because of herd immunity acting as an evolutionary pressure or because herd immunity against one strain allowed another already-existing strain to spread. Emerging or ongoing fears and controversies about vaccination have reduced or eliminated herd immunity in certain communities, allowing preventable diseases to persist in or return to these communities.On a global scale the large number of corona virus cases are essentially a small percentage of over 750 crore people of the world to think realistically of herd immunity as protection unless a vaccine is developed, administered and implemented to enough people.Hence what we find out is that herd immunity is basically a failure, because by the time it reaches the stage of success a lot of damage is already done.

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