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RESEARCH ARTICLE

MANGANESE NODULES, ITS PROSPECTS AND CHALLENGES

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Abstract

Manganese (Mn) is not only one of the important elements in the earth's crust, which is essential to iron and steel production, aluminum alloys, an additive in unleaded gasoline, the reagent in organic chemistry etc, but also an essential element for human health, metabolism, and antioxidant system. The Mn deposits are of interest because they contain greater amounts of other metals that are found in today's known economically minable deposits. High quantity of Co, Ni, Cu, and Zn containing in the Mn deposits makes it a significant potential economic resource for these elements. The most identified deposits of manganese are in South Africa, Australia, China, Brazil, Gabon, Ukraine, India, Fiji, Ghana, and Kazakistan. Besides the inland deposits, a huge amount of Mn nodules deposits (several times more than the economically minable deposits on land today) have been identified in different ocean basins at approximately about 3500 to 6500 meter (m) depths especially in the Pacific and the Indian Ocean. But mining Mn nodule in the ocean basin at an industrial scale is presently not usual because there are no market-ready mining machines. Moreover, at present, environmental impact on ocean basin due to mining takes attention to the society. Future research and time being mining technology will be economically feasible for Mn nodules mining in different ocean basins.

Introduction:-

Manganese (Mn) nodules are also known as the polymetallic nodules. Mn is the ninth or tenth most abundant element in the Earth's crust (Glasby, 1984). Accordingly, in the deep-sea floor enormous quantities of Mn nodules are present. These nodules, with a size ranging from that of a potato to a head of lettuce (Fig. 1), include mostly Mn, as their name imply, but also contain iron, nickel, copper, titanium, cobalt etc. The formations of huge quantities of Mn nodules in the deep-sea floor due to the fact that it migrate from less oxidizing to more oxidizing environments and then precipitate. In the seawater, it occurs generally as Mn^{2+} or $MnCl^{+}$ (Bruland, 1983). About 90% of Mn commenced to the oceans from a hydrothermal source (Glasby, 1988). Hydrothermal Mn differences in seawater can be identified over 1,000 km from the source in the Pacific Ocean (Burton and Statham, 1988). The Mn nodules produced in the sea bottom since the lower Miocene unconformity (12 Ma) and it's contain about 16 times more Mn than terrestrial deposits (Glasby, 1988) and therefore reflecting the significance of Mn nodules in the global cycle of Mn. However, the high proportion of Co, Ni, Cu and Zn in Mn manganese nodules makes it a significant financial reserve for these elements. But the Mn nodules extraction from the sea bottom has been a subject of curiosity since the 1960s (Glasby, 1970) due to technological challenges. Although, a huge amount of investment in deep-sea

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mining over more than 40 years, but there has still been no successful attempt to mine the sea bottom nodules on a profitable level (Glasby, 2013).

Though, no profitable level deep-sea mining has taken place, but some shallow sea-bed ~~see-bed~~ mining operations are active (Miller et al., 2018). Some companies from China, the United Kingdom, Belgium, Germany, France and Japan contracted with International Seabed Authority (ISA) for three different mineral resources: seafloor massive sulfides (SMS), ferromanganese crusts and Mn ~~pollymetallic~~ nodules. Many countries also operated deep sea mining for Research and Development (R&D) only ~~(R&D)~~ (Ham, 1997).

Although, till now there is no successful attempt for commercial mining but at present another vital topic i.e. evaluation of environmental impact due to mining takes attention to the society. Consequently, over the past few ~~5~~ years important environmental concerns were developed for mining in continental shelf regions (New Zealand Environmental Protection Authority, 2016). Due to seabed mining, negative impacts on biodiversity are predictable and possible to be irreparable (Van Dover et al., 2017). Neilsen et al., (2016) stated that a number of deep-sea species with long life period (Greenland shark (*Somniosus microcephalus*),~~;~~ the black coral (*Leiopathese spp.*))~~, a deep marine species, is identified to have a colony lifespan of up to 2,320 ± 90 years, perhaps one of the longest living organisms on the globe~~ (Carreiro-Silva et al., 2013)) are exposed to physical disorder due to mining since of their slow development rates.

In this review, an effort was carried out to delineate the deep sea Mn nodules, its distribution, formation, resource potential, challenges of deep sea mining and future research direction by explain information from peer-reviewed and other scientific literature.

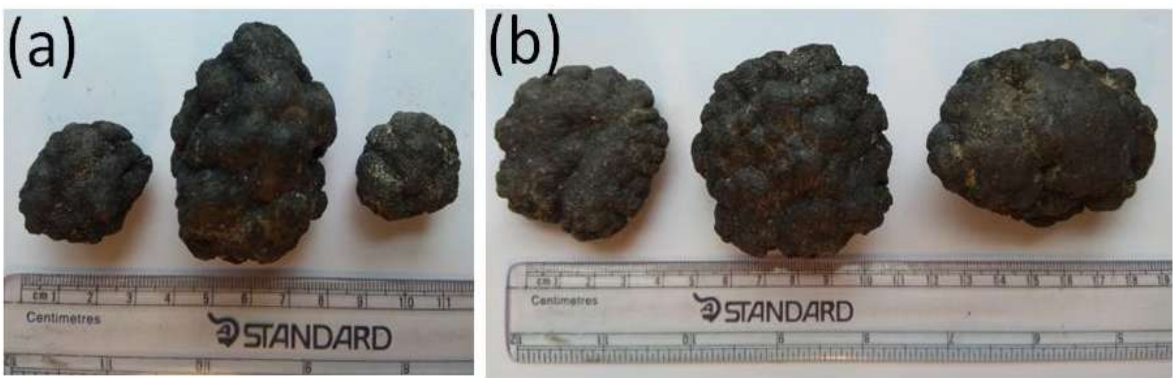

Fig. 1:- Nodules from the CCZ, Sample Collected at №9201-1Tp, RV GELENDZHIK cruise, JSC Yuzhmorgeologiya, Russian Federation (October, 2017- January, 2018) (13°03.537'N, 134°11.576'W; Depth: 4812 m).

Distribution:

The distribution of elements in deep sea sediments were described in many researches (Bischoff et al., 1979; Stoffers et al., 1981, 1985; Meylan et al., 1982; Aplin and Cronan, 1985; Baturin, 1988; Chester, 1990; Glasby, 1991; Miller and Cronan, 1994). Mn nodules are found in many ocean basins (Fig. 2). It occurs throughout the world ocean, principally on the surface of sediment-covered abyssal plains at water depths of around 3500 to 6500 m. However, some nodules found which partially buried in the sediment and others are totally buried. The distribution of Mn nodules in the Pacific Ocean was mapped under the Project of the Circum-Pacific Map by using 2,500 bottom camera stations and from sediment cores (Piper et al., 1987). Andreev and Gramberg (2002) published a map of the mineral resources of the world ocean, where they also included Mn nodules distribution of the ocean basins. However, in all the ocean basins, the Mn nodules are identified in considerable proportions in four regions of the world ocean: (1) clarion-clipperton zone (ccz), (2) peru basin, (3) penrhyn basin and (4) indian ocean (Hein et al., 2000; Jauhari and Pattan, 2000, Pattan et al., 2001; Balaram et al., 2006; Baturin and Dubinchuk, 2010, Pattan and Parthiban, 2011; Hein, and Koschinsky, 2013; Hein et al., 2013; Fig. 2).

Besides these four regions, the two eastern island groups of the Republic of Kiribati (Phoenix and Line Islands) have high abundance of nodules. The western Kiribati group (Gilbert Islands) and within the EEZ of the island nations Tuvalu and Niue have also Mn nodules but to a lesser extent (Secretariat of the Pacific Community, 2011). Several other deposits were also identified in the Argentine Basin in the SW Atlantic and in the Arctic Ocean. But still these are poorly explored (Hein et al., 2013).

Clarion-Clipperton Zone (CCZ):
The area of this zone is about 9 million square kilometers, roughly the dimension of Europe and world‘s biggest Mn nodule deposit in the ocean bottom. It is situated in the Pacific, extending from Hawaii to the west coast of Mexico. However, the nodules in this region are not consistently disseminated. The nodules are more heavily in some areas. But in stony areas there are no nodules. This zone consists around 15 kilograms (kg) of nodules per square meter (m^{-2}). But some areas can have up to 75 kg. However, this zone has about 21 billion tonnes of Mn nodules.

Peru Basin:
This basin is located about 3000 kilometers (km) far away from the Peru coast. It is about half of the CCZ. It consist an average of 10 kg of Mn nodules m^{-2}.

Penrhyn Basin ~~basin~~:
This is the third significant Mn nodules ~~nodule~~ basin in the Pacific Ocean. It is lies near to the Cook Islands, a few thousand kilometers east of Australia. It is about 750,000 square kilometers (km^{2}). It consists about 25 kg of Mn nodules m^{-2} of the ocean bottom.

Indian Ocean:
It is lies in the central Indian Ocean and area similar to that of the Penrhyn Basin. Only a single big area of Mn nodules was discovered in this Ocean. This area consists about 5 kg of Mn nodules m^{-2}of the ocean floor.

Fig. 2:- Mn nodules distribution of the world oceans (modified after Hein et al., 2013).

Formation:
The Mn nodules generally occur in deep water (>4,000 m) in sea bottom where the sedimentation rates are very low. These are typically developed concentrically around a distinct nucleus (Jiang et al., 2017; Fig. 3). Development takes place mainly at the sediment-water boundary. Dissolved metal compounds in the ocean water accumulate over time surround a nucleus of several types on the sea floor. The growth core can be, for example, a shark’s tooth or a

piece of a clam shell, surround which the nodule develop. More extensive reducing situations on the seafloor, happened by enhanced surface-water productivity, could cause mobilization of Mn oxides from deep-water sediments into the mid-water column, and their relocate to shallow-water sediments where the upper margin of the oxygen minimum zone intersects the ocean bottom (Koschinsky and Halbach, 1995). At this location, Mn^{2+} can be re-oxidized to insoluble Mn oxide, which falls to the seafloor where it is transformed to Mn carbonate during early diagenetic reaction with organic substance (Calvert and Peterson, 1996). Since Mn nodules deposit mostly in deep ocean basins and consequently it's occur in highest proportions on red clay and siliceous ooze area far from land i.e. main oceanic basins. The distributions of nodules are also related to the patterns of oceanic bottom water flow and, to a lesser extent, to the accessibility of possible nuclei on which they develop. Antarctic Bottom Water (ABW) is the main oceanic bottom current in the Pacific. Its control is seen in the lowered sedimentation rates and consequently increased nodule abundance, along with its flow path (Mero, 1965; Horn, 1972; Glasby, 1977; Bischoff and Piper, 1979; Sorem and Fewkes, 1979; Cronan, 1980; Roy, 1981; Teleki et al., 1987; Baturin, 1988; Halbach et al., 1988; Nicholson et al., 1997; Cronan, 2000).

There are three principal modes of formation of the Mn nodules (Glasby 1977; Fig. 3): (1) Hydrogenous deposit, (2) Diagenetic deposit, (3) Mixed source deposit.

Hydrogenous deposit:
This deposit occurs directly from seawater in an oxidizing environment and characterized by slow growth (about 2 millimeter per million years (mm Ma^{-1})). The high Mn/Fe ratio in deep sea water compared to the earth's crust is mainly responsible for the formation of hydrogenous manganese deposits.

Diagenetic deposits:
It results from diagenetic processes within the underlying sediments leading to the upward supply of elements from the sediment column. These deposits are characterized by faster growth rates (10-100 mm Ma^{-1}) and are often found on siliceous oozes.

Mixed source deposit:
This deposit occurs both from seawater in an oxidizing and diagenetic processes.

Composition:
The Mn nodules consist mainly of Mn and Fe ~~manganese and iron~~, although considerable proportions of other metals are found (Miller et al., 2018). The Mn ~~manganese~~ in seawater adsorbs to a nodule material that is oxidized by bacteria and becomes nodule matrix (Blöthe et al., 2015; Vanreusel et al., 2016). However, the growth rate of Mn nodules is very slow. It takes million of years for several mm to several cm of growth (Halbach et al., 1980). It consists normally manganese (28%), nickel (1.3%), copper (1.1%), cobalt (0.2%), molybdenum (0.059%), and also rare earth metals (0.081%) (Hein et al., 2013). It also consists traces of other valuable materials counting tellurium and platinum (Hein et al., 2013; Antoni et al., 2017; Ojo and Dharmadasa, 2017; Miller et al., 2018). However, the composition of nodules is not uniform (Miller et al., 2018). The nodules found immediately some 100 m apart can differ noticeably in composition. However, the concentration of minerals in nodules found in the North Pacific region is greater than the South Pacific. In the North Pacific region the percentage values were reported as: Mn 22-27; Ni 1.2-1.4; Cu 0.9-1.1; Co 0.15-0.25; Fe 5-9 (Halbach et al., 1980).

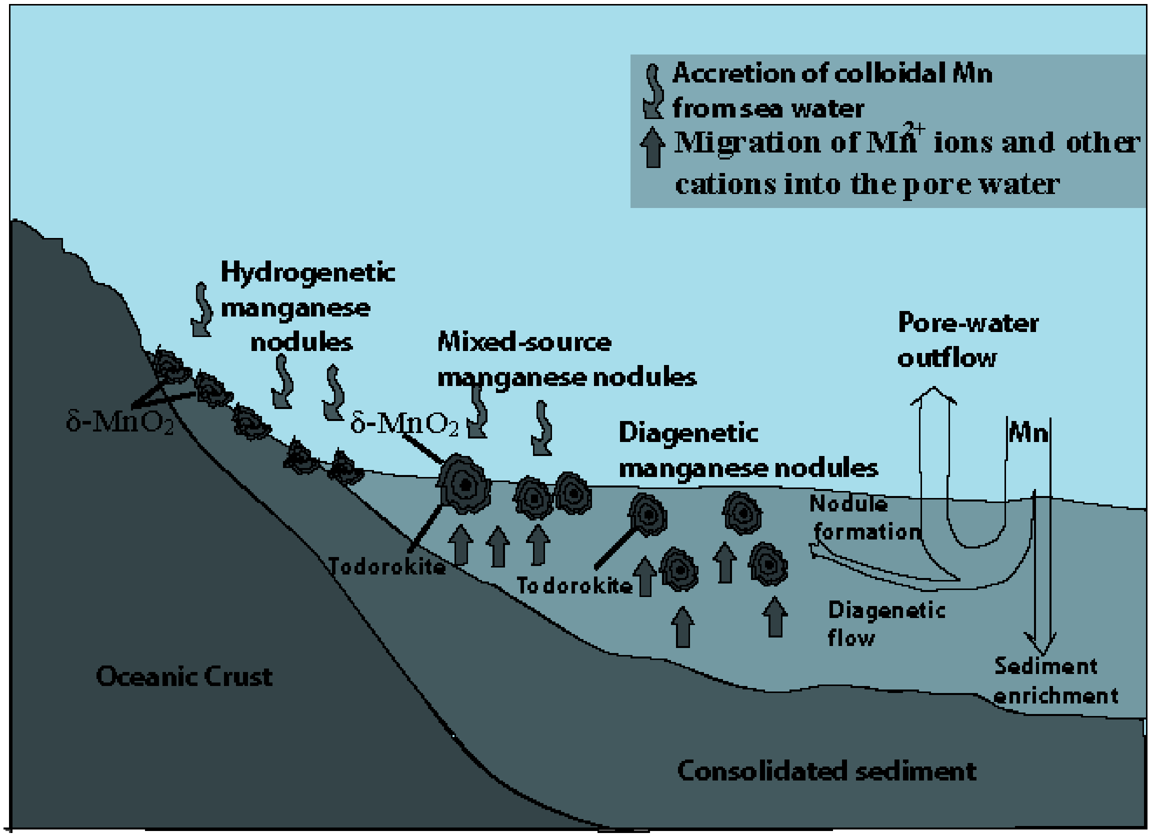

Fig. 3:- Diagram of formation of hydrogenetic, diagenetic, and mixed-source Mn nodules by precipitation from seawater and/or sediment pore water (modified after Hein et al., 2013).

Resource Potential:
The Mn nodules that contain mainly manganese but also some valuable metals made the deposits of great interest. The CCZ alone has nearly 10 times more Mn than the economically minable Mn deposits on land today (Hein et al., 2013). The nodules from the North and South Pacific Ocean contain at least 1% copper and nickel (Miller et al., 2018). The CCZ alone hold 3 and 6 times more Nickel and Cobalt respectively than the economically minable deposits on land today (USGS. Mineral Commodity Summaries 2020 ttps://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf).

Most of the countries of the world that do not have access to their own land Mn reserves and consequently they depend on imports from other countries. Therefore, recovering metal resources from deep sea mining considered as one of five sectors with a high potential for development within the European Commission's (EC) blue growth strategy (European Commission, 2017). The EC aims to offer support to long-term sustainable development in the marine and maritime sectors within the region, and they hopefully estimate that by 2020, 5% of the world's minerals could be sourced from the sea bottom (Ehlers, 2016). They also estimated, if technological challenges are overcome, the annual revenue of marine minerals mining within Europe could raise from zero to 10 billion Euros by 2030 (Ehlers, 2016). But the resource potential of Mn nodules in the world ocean is still a significant uncertainty due to technological challenges and consequently a considerable uncertainty in projecting the time frames of the beginning of exploitation of polymetallic nodules (Hein et al, 2013; ISA, 2020). Moreover the deep-sea mining, its commissioning will create risks for land producers. However, the extent of their impact will largely depend on the supply/demand balance that will actually emerge in the market by the time it begins and will remain as it increases (ISA, 2020). However, many countries seek license from the ISA ~~International Seabed Authority (ISA)~~ due to exploration and exploitation of sea bottom minerals. Consequently, till now, the ISA approved 21 exploration contracts of different mineral resources from sea bottom (www.isa.org.jm/deep-seabed-minerals-contractors). Of these contracts, eighteen are for the exploration for Mn nodules, in the CCZ (16), ~~and~~ Central Indian Ocean Basin (1) and Western Pacific Ocean (1). After granted the exploration contracts then parties are entitled to discover for minerals over a selected area of the sea-bottom. Contracts are applicable for 15 years, after which the contract can be extended for an additional 5 years. At present, the entitled exploration area allocated to each contractor is 75,000 km^2.

Technological Challenges:
The available sea bed minerals mining activities are based on almost similar model of using a ocean bottom collector, a lifting system and a maintain ship engaged in offshore processing and transporting (Blue Nodules, 2016; Jones et al., 2017; Miller et al., 2018). However, the Mn nodules mining from the deep ocean basin at an industrial scale still infancy because there are no market-ready mining machines (Hein et al., 2013). Although China, Japan, South Korea were built prototypes in recent years and also employed them in the sea, but these still need to improve. Since the Mn nodules normally accumulate in deep water (>4,000 m) and therefore it still has to be adapted for water depths of >4,000 m. Furthermore the working conditions on the high seas. Also, the machines for Mn nodule nodules mining have to withstand the high pressures at high water depths. Furthermore, it must be able to work dependably over long time periods, because maintenance on deep-sea equipment is tremendously expensive and also starting with the raising of up to 250-tonne machines to the surface. A few years ago the German Federal Institute for Geosciences and Natural Resources invited tenders for a design study for appropriate deep-sea machines that Germany wants to deploy in its own license area in the CCZ (Hein et al., 2013). The participating companies included one that already made machines for diamond mining in the Atlantic off Namibia. However, the equipment for diamond production, they deployed in only 150 meters of water depth and near the coast. But the Mn nodules preserved in the deep oceans basins. Therefore, still it is a big challenge of the scientific community to build appropriate machineries for Mn nodules mining from the deep ocean which is economically viable. Though there is a large body of literature on prospective technologies for the investigation and exploitation of deep-ocean mineral deposits (Hein et al., 2000). However, only the first generation technologies for exploitation are available now or are presently being built for the mining of Mn nodules.

Environmental Impacts:-
The ISA was established in 1982 by UNCLOS and is an independent intergovernmental body with 167 members. The ISA is solely authority for the regulation and manage of mineral-related action in the area of international sea (Area) comprised of the States Parties to UNCLOS. Three sections in UNCLOS are mainly related to deep-sea mining: Article 136, Article 137.2, and Article 145, which correspondingly cover the common heritage of mankind, resources and the protection of the sea environment. The ISA judges applications for exploration and exploitation of deep-sea resources from parties, evaluates environmental impact assessments and controls mining activities in the Area.

However, till now ISA only looked-for to execute policies connecting to investigation. But at present, as importance in commercial exploitation move ahead, the ISA is currently in the process of forming a regulatory body for exploitation. Consequently, an operational outline titled "Regulations and Standard Contract Terms on Exploitation for Mineral Resources in the Area" was issued in July 2016, and a dialogue paper, "Regulations on Exploitation for Mineral Resources in the Area (Environmental Matters)" was prepared public in January 2017 (https://www.isa.org.jm/files/documents/EN/Newsletter/2017/Mar.pdf). Besides, on the ISA website, a report from a seminar held in Berlin, Germany, in March 2017 to build up a long-term ecological policy for the high sea is available (https://www.isa.org.jm/document/towards-isa-environmental-management-strategy-area). However, after the Berlin workshop, the ISA also released modified draft regulations in August 2017 titled, "Draft Regulations on Exploitation of Mineral Resources in the Area" among a t list of questions to be addressed (https://www.isa.org.jm/files/documents/EN/Regs/DraftExpl/ISBA23-LTC-CRP3-Rev.pdf).

However, the management of environment of exploitation area will engage various levels of evaluation, some of which will be carried out by the ISA and some by parties (Miller et al., 2018). But till now the extraction policies does not outline environmental management in detail and definite procedures (Miller et al., 2018). At present ISA only prepared the regional environmental assessments for smaller zones within the Area and then contractors would commission environmental impact evaluations and reports for the particular area of their contracts (Miller et al., 2018). But, details of how the ISA will handle the ecological facts related to extraction have not been finalized (Miller et al., 2018). Therefore, here is a lack of documented outline ecological information and questions wait, together with what body will supervise and observe areas of definite ecological importance.

The exploitation of ocean resources was first suggested in the 1960s and during that time, scant regard was given to environmental consequences (Miller et al., 2018). Several decades later, increasing figures of commercial companies are in the channel and they have been working in national and international waters. In parallel with business interest in sea bottom minerals, the rapid loss of marine species are also becoming evident and therefore establishing marine reserves and studies have attempted to evaluate the ecological impacts of mining (McCauley et al., 2015; O'Leary et al., 2016; Roberts et al., 2017; Miller et al., 2018).

The polymetallic ~~nodule~~ nodules ecosystem is an exclusive habitat for suprabenthic megafauna (Tilot, 2006). Though, extremely limited researches were carried out about nodule fauna on the abyssal plains. However, those researches, it imply that due to mining may result in considerable habitat loss (Glover and Smith, 2003; Veillette et al., 2007; Vanreusel et al., 2016). Several other researches also reported that the effects of nodule mining are immediate and severe, although signs of recovery were also observed but at most sites, there was a significant reduction in the number of recolonizing species (Bluhm, 2001; JPI, 2016; Jones et al. 2017).

The elevated densities of together sessile and movable fauna living on or close to manganese nodules than in nodule-free areas of the abyssal plains (Vanreusel et al. 2016). In nodule-rich areas, a documented 14-30 sessile individuals per 100 m^2, and 4-15 mobile individuals per 100 m^2; whereas in nodule-free areas there were up to 8 sessile individuals per 100 m^2 and 1-3 mobile individuals per 100 m^2. The outcome of several studies concluded that to inclusive evaluate the impacts on biodiversity due to mining will require long-term studies, because due to limited data on deep-sea ecology (MIDAS, 2016). However, MIDAS identified that seafloor habitats did not recover for decades following interruption. MIDAS also stated that small-scale experiments cannot precisely evaluate the complete consequences of habitat loss due to commercial-scale mining.

Since the growth rate of nodules is very slow and therefore the physical recovery of manganese nodules will take millions of years (Halbach et al., 1980; Gollner et al., 2017). Therefore, the removal of manganese nodules eliminates the habitat for nodule residence organisms, making revival of these communities almost not possible given the long time periods necessary for nodule development. The former experiments have shown that the tracks made by the mining vehicles were still clearly visible even after few decades later and also devoid of fauna which were rich in biodiversity before extraction of nodules and consequently indicating that mining can permanently damage nodule habitation and guide to considerable biodiversity loss (Miljutin et al., 2011; Vanreusel et al., 2016; Miller et el., 2018).

Due to mining, deep-sea sediment plumes will be created by seafloor production vehicles, particularly the collector as well as by risers and maintained equipment that is released as waste-water by the surface maintain ship (Boschen et al., 2013; Van Dover, 2014; Gollner et al., 2017). The discharge plumes are likely to impact habitats of the ocean bottom. Nautilus Minerals (2008) and Boschen et al. (2013) stated that the discharge of plumes from a sulfide test-mining at Solwara 1 resulted in sedimentation of up to 500 mm within 1 km of the release site and some substance also dispersing up to 10 km away. But the natural sedimentation rates are thought to be only few millimeters per 1,000 years in both abyssal and seamount habitats (Miller et al., 2018). However, still there are no potential plume movements models were established due to the absence of sufficient data on plumes, upwelling, and oceanographic currents (Luick, 2012; ~~Miller et al., 2028~~Miller et al., 2018). Moreover the commercial seabed mining has not begun and as a result it is hard to guess the impacts, but several land mining activities can help to foresee probable penalty of mining (Shimmield et al., 2010). The release of wastewater at the ocean surface could also impact marine ecosystems by creating turbidity clouds and distressing profitable fish species, and in some cases, causing algal blooms (Namibian Marine Phosphates, 2012).

The mining machineries generally increase underwater noise, but most of the deep-sea species only familiar with low-levels of noise, therefore such anthropogenic noise, particularly if happening on a non-stop basis, will significantly amplify ambient sound levels, consequently impact the species (Rountree et al., 2011; Bashir et al., 2012). Several researches reveal that a number of fish species and sea mammals effected by anthropogenic noise or permanent damage depending on the species, nature of noise and received level (Gomez et al., 2016; Nedelec et al., 2017). Moreover, sediment plumes and noise propagation can alter species distributions, ecosystem functioning or even apparently unconnected processes such as carbon cycling (Nath et al., 2012; Le et al., 2017). Furthermore, mining activities will result in the direct mortality of organisms, elimination and disintegration of substrate environment and deprivation of the water column and seabed by sediment plumes (Van Dover et al., 2017). Therefore, deep sea mining will definitely impact on biodiversity due to sediment plumes, noise and nodules removal.

Future Researches:

The population of the world reached to about 7.6 billion in October 2017 (Anon, 2017). Of them, more than 2.5 billion live in rapidly growing and middle income countries. Therefore, these people need to build the infrastructure and obtain the resources required to develop a sustainable energy in future. Many of the rare metals necessary for this growth and these are rich in deep-ocean Mn nodules. Though, these are limited in the land-based sources. Therefore it is difficult to fulfill the population demand only based on land-based resources and consequently maintain the sustainable growth (Nature Geoscience editorial, 2011; Ragnarsdóttir, 2008). Additionally, many essential metals have limited sources (Price, 2010). Furthermore, the grades of land-based mines are continuously decreasing (Mudd, 2009) and therefore Mn nodules are considered to be one of the most significant deposits of metals and other mineral resources in the ocean in the present day. Nevertheless, due to its big proportions of metals, it is definitely possible that the nodules may be mined in certain ocean regions in the near future.

But the resource potential of Mn nodules in the world ocean is still not well known due to technological challenge (Hein et al, 2013). However, it is vital to evaluate the sea mineral deposits so that their comparative importance can be understood as possible sources of many uncommon, tactical, and significant metals. Relative assessment should also include the complete life cycle of the commodities of interest and also the ecological explanation for each from a production point of view. Therefore, several important breakthroughs are necessary for mining to become feasible. The upcoming researches also need to measure the physical properties in situ of seawater-saturated samples. It is essential due to understand the methods of appropriation of metals from seawater. Although, already considerable progresses are being made in extractive metallurgy by different nations, however, more progresses are needed due to implement of cost-efficient green technologies (Hein et al, 2013). Since all the major and minor metals in nodules can be put into solution by a simple acid leaching, chemical and biochemical procedures to selectively recover the metals of interest should be developed (Hein et al, 2013). After that the remaining material might be passed on to a further removal operator to pick up extra metals of interest if the economic incentive is there-or the tactical require.

The ISA till now the mining policies on the deep seafloor does not outline about environmental management in detail and definite procedures (Miller et al., 2018). Though, the deliberations are in progress by ISA to build up the legal framework to control exploitation, including issues of ecological security, responsibility, and connections across global and domestic limits, and also between claims, with contribution from ocean researchers, legal experts, and different organizations (Miller et al., 2018). Therefore, the review reflecting that the revivals of deep-ocean biota due to seafloor mining are inadequate and it needs more study. It needs sufficient baseline data from prospect mining sites. But due to the logistical difficulty and economic constraints of accessing the deep sea, the data have not enough. Therefore the future research could focus on understanding deep-sea ecosystem in the future mining sites.

Furthermore, due to uncertainties about deep-sea ecosystem and environmental reactions to mining-related activities (Clark et al., 2010) indicate that ecological supervision strategies would require to be modified to integrate temporal and spatial changeability of deep-sea ecosystems ~~(Clark et al., 2010).~~ The impact of noise on deep-sea organisms is not also well known (Miller et al., 2018), which represents a further considerable knowledge gap in the supervision of commercial activities ~~(Miller et al., 2018)~~.

Additionally, the Mn nodules mining from the deep ocean basin at an industrial scale still infancy because there are no market-ready mining machines and consequently a considerable uncertainty in projecting the time frames of the beginning of exploitation of polymetallic nodules. Although China, Japan, South Korea were built prototypes in recent years and also employed them in the sea, but these still need to improve. Moreover the deep-sea mining, its commissioning may be will create risks for land producers. Although, the extent of their impact will largely depend on the supply/demand balance, but it needs to evaluate.

Conclusions and Recommendations:-

Huge quantities of ~~manganese~~ Mn nodules, nearly 16 times more than terrestrial deposits are present in the deep ocean basins. These nodules contain high proportion of Co, Ni, Cu and Zn which make it a significant financial reserve for these elements. Therefore, the Mn nodules extraction from the sea bottom has been a subject of curiosity since the 1960s. But the resource potential of Mn nodules in the world ocean is still a significant uncertainty due to technological challenges and also no market ready mining machinery. Although China, Japan, South Korea were built prototypes in recent years and also employed them in the sea, but these still need to improve, and consequently a considerable uncertainty in projecting the time frames of the beginning of exploitation of nodules. Although, till now there is no successful attempt for commercial mining but at present evaluation of environmental impact due to mining also takes a new attention to the society. The ISA is solely authority for the regulation and manage of mineral-related action in the area of international sea. Although, the management of environment of exploitation area will engage various levels of evaluation, some of which will be carried out by the ISA and some by contractors. But till now the extraction policies does not outline environmental management in detail and definite procedures. At present ISA only prepared the regional environmental assessments for smaller zones within the Area and then contractors would commission environmental impact evaluations and reports for the particular area of their contracts. Therefore, here is a lack of documented outline ecological information and also questions arise, what body will supervise and observe areas of definite ecological importance. At the same time, now exploration companies are increasing and they have been working in national and international waters. Consequently, in parallel with business interest in sea bottom minerals, the rapid loss of marine species are also becoming evident and therefore establishing marine reserves and studies have attempted to evaluate the ecological impacts of mining. Moreover, the polymetallic nodule ecosystem is an exclusive habitat for suprabenthic megafauna. But, extremely limited researches were carried out about nodule fauna on the abyssal plains. However, those researches, it implies that due to mining may result in considerable habitat loss. Several other researches also reported that the effects of nodule mining are immediate and severe, although signs of recovery were also observed but at most sites, there was a significant reduction in the number of recolonizing species. Moreover the deep-sea mining, its commissioning may be will create risks for land producers. Although, the extent of their impact will largely depend on the supply/demand balance, but it needs to evaluate. Therefore, future study about resource potential, overcome technological challenges, environmental impact assessment and policies, and time being mining machineries will be economically viable of manganese nodules mining from different ocean basins.

To achieve these, ISA can take some integrate plans also:
To create an international scientific body under ISA. This body cans help.

To buildup the suitable deep sea mining machineries for exploration and exploitation of deep-ocean Mn nodules, evaluate the resource potential of Mn nodules in the global ocean and also assess the population demand, although different nations try to develop the suitable sea mining machineries of their own.

Evaluate the impact on sea bottom biodiversity due to deep sea mining.

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