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A Review of Mineralization of Rare Earth Elements in Iran

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Abstract: Due to the increasing progress of modern technology, the increasing use of rare earth elements, the strategic nature of these elements, and the national need for these elements, the study and exploration of these elements are of great importance. Therefore, to achieve this goal, rare earth elements in different deposits in Iran were studied. Iran's highest concentration of rare earth elements is in phosphate and iron-apatite deposits and coal ash, respectively. It can also be noted that these elements are concentrated in bauxite and copper deposits along with alterations, laterites, and placers, requiring more detailed studies. According to these studies, the distribution of these elements in different deposits was determined. Also, the high dependence of these elements on different deposits such as phosphates was determined. Therefore, due to the growing need of the country for these elements, as well as self-sufficiency in this sector and even the export of these elements, emphasis is placed on further studies in the sectors that are considered promising and become waste dams. We are going to use it to explore new resources.

Keywords: REE, Mining Engineering, Geochemical Exploration, LREE, HREE

1. INTRODUCTION

Rare earth metals include scandium (Sc), yttrium (Y) and elements of the lanthanide group and are divided into two categories: light (La, Ce, Pr, Nd, Pm, Sm, Eu, Sc) and heavy (Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y) are divided. Some elements are not rare in abundance, but they cannot be concentrated due to dispersion in different minerals. Rare earth elements are also in this category. For this reason, it is more challenging to search, explore and extract rare earth elements than other elements. Rare earth elements, light earth rare elements and rare earth elements are abbreviated REE, LREE and HREE. [1]

In today's world, advanced technologies desperately need strategic elements such as rare earth elements, Which can be traced in essential industries such as the production of permanent magnets, metal alloys, coolants and catalysts.

It also has many applications in various chemical, metallurgical, military, aerospace, nuclear, optics and electronics industries, oil extraction and refining, automobile, nanotechnology, etc. Application of these elements in the manufacture of superalloys, oxygen sensors, fluorescent lamps, optical fibres, laser synthesis, computer memory and mobile phones, crude oil refining, permanent magnets, industrial engines for modern cameras and camcorders, medicine, Dentistry and ... more visible. [2]

In general, rare earth elements in terms of origin and origin in two types of primary mineralisation with intrusive igneous masses and veins, dykes, pegmatites and secondary mineralisation, including dunes and detrital placers and lateritic residues and Beach sand is found. Also, most of the world's rare earth elements are concentrated in carbonates, which are associated with the last stage of the magmatic series. The three main minerals include these elements, monazite, xenotime and anti-archaeite. [3, 4]

Significant reserves and sources of rare earth elements in the world include the Pass Mountains in southern California, the Bayan Obo Reserve in central Mongolia, and Kairona, Sweden. [5]

For the first time in Iran, researchers of the Amir Kabir University of Technology have extracted rare earth elements and produced metal ewes from the tailings of iron processing plants. Also, extensive and semi-extensive studies with geochemical methods and geochemistry and geology on areas such as magnetite-apatite deposits of Choghart, Chadormelo and Esfordi and phosphorous iron deposits in Central Iran and alterations and laterite and placer and in coal Coal ash, bauxite deposits, etc. have been done, which are discussed in this article. [6-10]

2. DISCUSSION

According to studies and studies on rare earth elements in Iran, these elements have been proven in various deposits or have exploratory hope. This paper discusses their location in different deposits and their importance in iron, phosphate, copper and alloy deposits, laterite and placer, along with coal, coal ash, and bauxite.[11]

2.1 Rare earth elements with iron deposits (magnetite - apatite)

Please Iron ores in the world have always been of great importance for political and economic reasons, so detailed studies on these ores and, in particular, the amount and distribution of rare earth elements in them have been done. Extreme Consumption of Minerals, especially Metals Rare earth elements, are generally not formed independently and are found with base metal deposits, especially iron. The most crucial type of iron deposits containing these elements is apatite iron deposits, which also have alternating amounts of phosphorus, in other words, rare earth elements with phosphorus. They are concentrated in apatite minerals. In the Bafgh region, due to the presence of apatite iron deposits, there are rich sources of rare earth elements. [12-15]

According to the studies of Moradkhani et al. (2015), the following results were obtained on the Narigan exploration area, located in the southern part of the mining area of rare Esfordi soil elements and black spot (which has been identified as rich in these elements). In the Narigan region, the presence of semi-deep granitoid intrusion mass called Narigan granite as the source of mineralisation and joint system and fault system and many joints around the mass has created suitable conditions for forming metal veins. From this point of view and studies of the origin of rocks in these areas that are consistent with each other, there is a possibility of rare earth elements in the Narigan iron mine and the surrounding area. [16]

In another study in the Bafgh region, on the Choghart mine, which is located 13 km northeast of Bafgh and 120 km from Yazd, geologically, the complex that forms the rock inside the Choghart mine has two completely different facades. : Geologists have dubbed these quartz- and feldspar-rich rocks quartzite, porphyry quartz, granofir, plagiofir, keratofir and albitofir quartz, and rocks with a high percentage of actinolite of thermolite and feldspar (albite) and alter parts Amphibolitized, which is referred to as amphibolite, amphibole pyroxenite, hornblende and metasomatic with different compounds, we achieved the following results. Choghart iron deposit is considered one of the most crucial mineral potentials of iron and rare earth elements in Iran. In order to identify the rare elements of Choghart ore and determine their amount, samples from different parts of ore, mineral tailings and tailings of processing plants were prepared and studied using ICP, XRD light microscope and electron microscope. The results show that apatite and monazite are other valuable minerals after magnetite and hematite. Zones with high phosphorus are also due to the increase in these minerals. Analysis of different samples shows that the amount of rare elements is strongly related to the amount of phosphorus, and these two have a high correlation of r = 0.987. The amount of rare elements present in the development plan processing tailings is higher than the ore and mine tailings samples. About 97% of the rare elements in the samples are rare earth elements. These elements include cerium (Ce), lanthanum (La) and neodymium (Nd), which even amount to 1205,540,467 ppm, respectively. Only the amount of yttrium (Y) is significant in the group of rare earth elements. Most of the rare earth elements are independent minerals of monazite or inclusions or inclusions within apatite. Many rare earth elements have also been substituted for calcium $Ca2 +$ in the apatite mineral network. [17]

In another survey on the north-northeast side of the Choghart iron mine to investigate the petrography of rare earth elements, sampling was systematically performed. To determine the principal and rare earth elements, thin and polished sections were prepared and studied microscopically after preparing the samples. The results showed that the primary ore in the northeastern part of the Choghart deposit contains a large amount of massive magnetite. The sub-minerals include apatite, pyrite, alkaline amphiboles, especially actinolite and thermolite, calcite, talc, quartz, monazite and bastnasite. Air ores are found in orthopaedics and yellow matter, with apatite being the main constituent of these elements in the region. [18]

In another study by Shekarian et al. On the Choghart deposit, due to the complex geological structure and the effect of grade distribution in this deposit, more detailed studies on grade zoning and creation of grade distribution models following geological structures by the method The separation of mineralisation zones from a geological and geochemical point of view and the relationship between the obtained models and rock units were investigated by fractal geostatistical method better to understand the distribution of rare elements by these models. The soil in the deposit is to be provided for further studies. For this purpose, they use fractal modelling by the carat-number method to separate different mineralisation zones and justify the distribution of carat based on lithological models and geochemical communities. Fractal geometry and lithology confirmed the relationship between the zones separated by the grade-number method and the lithological model. Metasomatic and albitofer type and a sub-community b The name of phosphorus iron type, which is a subset of phosphate type, exists in the region in which special attention can be paid to rare earth elements. [15, 19-21]

In another study by Moghiseh et al. (2014) in the tailings dam of the Choghart iron plant, in order to pre-concentrate the rare earth elements, the reagent sample was removed, and XRF analysis was performed on the sample with cerium, lanthanum, neodymium with 120, 98 and 350 ppm of light rare elements and yttrium, gadolinium and erbium with 630, 110 and 23 ppm of heavy rare elements showed the highest values, respectively. According to the results of minerals identified in XRD and the properties of rare earth minerals, a series of processing operations were performed on it, which have the grade of cerium, lanthanum, neodymium, and yttrium, gadolinium and erbium, respectively, equal to 4.335, 4.278, 1010. 8.8, 1907, 322/8, 4.66 ppm and the recovery of these elements were 60, 61, 62, 65, 63 and 62%, respectively. $Fe2O3$ grade was 10% in this section. [22]

Shirzaei et al. (2014) studied the northern anomaly located 11 km northwest of the Choghart iron mine, divided into three massifs: eastern, central and western due to tectonics. The central massif of this deposit was studied in terms of reserves of valuable elements. First, this information was analysed by collecting the information from the central massif. Then by preparing the information resulting from the excavations and drawing the geological profiles of the three-dimensional model of the central massif of this deposit and the number of rare earth elements stored In this massif, it was evaluated using the software. Finally, the amount of rare earth elements stored in the central massif of the anomalous northern deposit has been compared with several deposits in different continents. [21, 23-25]

Hazarkhani et al. (2014) investigated the geochemistry of rare earth elements in apatites and magnetites of Choghart iron deposits after sampling from the study area and chemical analysis of samples by ICP-MA EMPA and XRF methods, case samples Geochemical analysis was performed. Spider diagrams normalised to chondrite were drawn for all host rock types (albitofer), mineral, metasomatic and phosphate. The results showed that in all types, the enrichment of light rare earth elements is higher than heavy rare earth elements and spider diagrams with Eu negative anomaly, one of the main characteristics of alkaline ultrabasic magma. The results also showed that the distribution of REE in apatites and magnetites of Choghart iron ores is similar to that of Kirona type iron ores in other parts of the world, and the concentration of these elements in Choghart depends on the type of concentrating mineral which is fluorite apatite. [26]

In another study by Lak et al. (2013), the Balestan iron ore deposit, located 55 km southeast of Urmia city, West Azerbaijan province, was studied, and the following results were obtained for rare earth elements. The mean values of LREEs and HREEs in iron ores are 13.30 and 22.4 ppm, respectively, which are a sign of poor enrichment of these elements and require further investigation in other zones, as well as the presence of negative Ce anomalies. Iron ores indicate high fluoride content in ores and complexes (Ce (+4) with fluoride ligands. [25, 27-30]

In a study conducted by Mirzaei et al. (2016) on the Hassan Salar iron deposit, which is located 29 km south of Saqez, the behaviour of rare earth elements in the alterations of the region has been studied. The addition or reduction of a particular mineral has caused a change in the pattern of behaviour of rare earth elements. During potash alteration, rare earth elements were almost immobile, but the Eu element was sharply reduced. Filic alteration, except for the Eu element, increased compared to unaltered rock, while in propylitic alteration, which is more extensive than potassic, rare earth elements decreased sharply. [31, 32]

2.2 Rare soil elements along with phosphate deposits

Esfordi mining area, located 30 km northeast of Bafgh, is one of the country's essential sources of phosphate ore containing rare earth elements. This deposit contains three rare earth elements: cerium, lanthanum, and neodymium. According to the analysis of the control sample with OES-ICP, the amount of each of these elements is 5510, 2220, and 1980 ppm, respectively, which indicates the richness of these elements in this region. Be. Also, the amount of phosphorus in the control sample is 31.25%, which shows the high correlation of these elements with phosphate mineralisation. [33, 34]

In another study by Cheshmeh Sari et al. (2012), the Lar phosphate deposit in the southeast of Dehdasht, Kohkiluyeh and Boyer-Ahmad provinces was investigated. The host rocks of this deposit are limestones, shales and marls of the Pabdeh Formation to the Eocene-Oligocene age. Mineralogical studies show that these deposits contain calcite, quartz, francolite, dolomite, glauconite, illite and pyrite, which are accompanied by secondary minerals such as fluorine apatite, kaolinite, crandallite, hematite and goethite. Examination of the distribution process of elements in a selected profile reveals that elements such as P, REE and U are washed from the upper parts of the profile and enriched in the lower parts. The distribution pattern of normalised REEs to the Australian Archean (PAAS) shale composition shows poor subtraction of LREEs from HREEs and negative and weak Ce and Gd anomalies during phosphating. These features indicate La / Ce ratios well that changes in the chemistry of aerating solutions such as pH and weathering intensity are the two main factors that affect the mineralogy and distribution and stabilisation of REEs U and P in Lar phosphate deposits. Have put. Correlation coefficients between elements suggest that minerals such as apatite, granite, iron oxides, zircon and clay minerals are possible hosts for REEs and U. [35] [36-39]

2.3 Rare earth elements along with copper deposits

Songun copper mine, located 130 km northeast of Tabriz, northwest of Iran, was studied by Hassanzadeh et al. (2011) to investigate the scattering pattern of rare earth elements. The formation of this deposit is attributed to the hydrothermal activity associated with quartz monzonite stock monzonite and several granodiorite dykes that have penetrated the Cretaceous and Eocene sedimentary and volcanic rocks in the Oligocene to Miocene. In terms of lithography, Cretaceous volcanic rocks have a combination of carbonate and Chile. According to field observations and microscopic studies (presence of pyrite, chalcopyrite, colitis, calcite, quartz, clay minerals, plagioclase and chlorite). The main alterations observed in the massifs from the outside massif were potassic, phyllic, argillic and propylitic, which are indicators of porphyry copper deposits of the continental margin type. Geochemical studies show that rare earth elements in all three alteration zones have undergone both stabilisation and leaching processes. The distribution pattern of normalised REEs to chondrite implies the differentiation of LREEs from HREEs and the occurrence of Eu-negative anomalies during alteration. The results obtained from geochemical studies suggest that the effects of the tetrad, stabilisation in Neomorphic mineralised phases, the chemical composition of the primary rock, and change in water-to-rock ratio have been factors that play a valuable role in the distribution, mobility and enrichment of rare earth elements in The alteration system of the region has been played, so in order to explore these elements in this deposit, the factors mentioned above should be considered. [36, 37, 40-42]

Since metallic and non-metallic mines in South Khorasan province are suitable for discovering strategic elements such as rare earth elements, uranium, etc., Shirazi et al. South Khorasan Province; paid. These studies, despite small investments, can provide a platform for mining to flourish. In a case study on a copper deposit of coppersmiths located in this area, despite the potential of copper metal, it can be investigated to discover the ideal storage of yttrium. Yttrium may be enough to extract yttrium after extraction and further investigation. It is recommended that analyses be performed on mine tailings as well. [43]

2.4 Rare earth elements (hopeful) along with alterations

In a geochemical study of rare earth elements in the Shelah Baran region, two kilometres northeast of Ahar city and in the southeastern part of Qara Dagh batholith, East Azerbaijan province, by Mohammadi et al. (2014), The following results can be inferred about rare earth elements Appeared. Field observations and petrographic studies show that Eocene volcanic igneous rocks in this area with a combination of dacite tuff and trachyandesite along with Oligocene intrusive igneous rocks with a combination of diorite, quartz monzonite, and granodiorite are altered by hydrothermal fluids and in parts of It is associated with metal mineralisation, especially copper. Alteration zones in the rocks mentioned include phyllite, proplitic, intermediate argillic, advanced argillic, siliceous and biotite zones. The results of calculations of mass changes of elements using the Isocone method reveal that the development of the advanced argillic alteration zone associated with Eocene dacite tuffs with depletion of elements such as Mn, P, V, Cr, Co, As, Sr, Hf, Zr, Th, K, Si, LREE, C, Ba, Rb, Se, Zn, S, and enrichment of elements such as Mg, Cr, Na, Al, Ti, Cu, Fe, Pb, HREE, Y, Ga, Nd, Sn is included. The results of mineralogy and geochemistry of mass changes show that factors such as pH of alterating solutions, oxidation potential, differences in the stability of primary minerals, scanning by metal oxides and hydroxides, adsorption, and entry of metal elements by hypogenic solutions. The system, differences in the degree of alteration of the primary rock and changes in the ratio of water to rock have played an essential role in the degree of mobility, distribution and stabilisation of major, partial and rare earth elements in the advanced argillic alteration zone of the floodplain area. In particular, Y and HREE and considering the factors mentioned above, we can hope for exploration in this area and conduct further studies on this area. [44-48]

A geochemical study was performed on rare earth elements in the Mahour Chahkaleh area, 44 km northeast of Nazanz city, Isfahan province. Field observations and mineralogical studies indicate that the intrusion of the Oligocene granodiorite stock into the Eocene andesitic and Thracian andesitic rocks in this area has been associated with the development of a significant alteration system and metal mineralisation. Alteration zones in andesitic and trachyandesitic rocks include three potassic, two phyllic, three propylitic and four argillic. The distribution patterns of normalised REEs to the chondrite reveal that the differentiation of LREEs from HREEs has been associated with Eu-negative anomalies during the formation of phyllic, propylitic, and potassic alteration zones. The argillic and potassium alteration zones contain the largest and lowest quantities of REEs, respectively, according to the chemical analysis findings. Investigation of element enrichment factors indicates leaching and stabilisation of REEs during the development of alteration zones. Studies reveal that the high activity of sulfate coagulants combined with the low pH nature of alteration solutions is the main reason for the depletion of REEs in the potash zone, and the adsorption coupled with the low activity of sulfate coagulants is the leading cause of REE enrichment in the argillic zone. The results obtained from geochemical studies suggest that the distribution of REEs in the alteration zones in Mahour Chahkaleh is a function of changes in the physical and chemical conditions of the alteration environment, differences in the intensity of adsorption and scavenging by metal oxides, and the presence in phases. Mineralisation has been resistant. Therefore, further studies on the argylic zone are recommended due to enrichment. [49-52]

Zonooz kaolin deposit is located 15 km northeast of Marand, East Azarbaijan province, which was investigated by Alipour et al. (2010). In field studies (based on physical features such as colour, five distinct types of kaolin, including (1) white, (2) lemon, (3) grey, (4 brown and (5) yellow, were identified in this deposit. Field evidence And petrographic studies show that this deposit is genetically related to trachy andesitic rocks. According to the mineralogical findings of this deposit, including quartz, kaolinite, montmorillonite, calcite, pyrophyllite, chlorite, muscovite-illite, dolomite hematite and anatase, The study of element enrichment factors shows the performance of alteration processes on the rocks and, Yb, Tm, Cu, Hf, Zr, Ba, Rb, V andesitic trachea during the development of Xenoz kaolin deposit by washing elements such as Ga, Y, Ni, Cr, Co, Th, Sr, Cs and leaching-stabilisation of elements such as, Ta and, Nb, U were accompanied by enrichment of elements such as Lu. , Ho, Dy, Tb indicate that the physicochemical conditions of the alteration medium, the relative stability of the primary minerals, and the stabilisation in the mineral phases have played a role in this deposit. Manganese oxides, zircon, anatase, hematite, muscovite-illite, chlorite, cyanite, and in this deposit are essential morphs in geochemical distribution. Secondary phosphates (monazite, rhabdofan, xenotime) host REE in this deposit and can be substantial. [53-55]

Taghizadeh et al. (2010) explored the Baavaran Kaolin Reserve, 35 km northeast of the Middle East, East Azerbaijan Province. Field evidence and laboratory studies indicate that this reserve was developed from the alteration and weathering of oligomycin dacite rocks. Mineralogically, this reserve includes kaolinite, quartz, illite, cristobalite, muscovite, orthoclase and goethite. The results of calculations of mass changes of elements with the assumption of Al as immobilised index elements show that the performance of alteration processes on dacite rocks during the development of Baavaran kaolin deposit by leaching of elements such as Rb, enrichment of elements such as Sr, Th, Nb, Hf, Y, Ta, Ga, Pr, Nd, Sm, Eu, Gd, Yb, and Lu, and wash and stabilise elements such as Ba, Cs, U, Zr, V, Co, Cr, Ni, Cu, La, Ce, Tb, Dy, Ho, Er, and Tm were associated. The results indicate that factors such as pH changes of alteration solutions, adsorption, scanning and concentration by metal oxides, presence in resistant mineral phases, homogeneity of mother rock, the overlap of supergene processes on hypogenic processes and stabilisation in neomorphic mineral phases have played a valuable role in the distribution of rare earth elements in this reserve. Further geochemical considerations indicate that zircon, Ti-containing phases, serpentine, and secondary phosphates (monazite, rhabdofan, and xenotime) are the hosts of rare earth elements in this reserve that require further investigation. [50, 56-59]

2.5 Rare earth elements with laterite and placer

For The following results were obtained from the geochemical study of rare earth elements in the laterite Zan deposit, 25 km southeast of Damavand, Tehran province. This deposit is developed as a stratigraphy in the Chilean and sandstone basins of the Shemshak (Jurassic) Formation. Mineralogical findings indicate that the minerals of this deposit include diaspora, hematite, goethite, anatase, kaolinite, boehmite, siderite, rutile, quartz, titanomagnetite, zircon, and pyrite. The lateritization process in Zan has been accompanied by the enrichment of elements such as V, Y, Co, Cr, Ni, Nb, Zr, Fe, Ti, Al and REEs and the washing and stabilisation of elements such as Ba, Sr, Mn, U and Ca. Combining the results obtained from mineralogical and geochemical studies suggest that changes in pH of aeration solutions, oxidation potential, adsorption, presence of organic matter, preferential adsorption by metal oxides, presence in resistant mineral phases and stabilisation in neomorphic phases play a valuable role in the distribution of major, minor, and rare earth elements in the laterite deposit. The correlation coefficients between the elements suggest that zircon, rutile, gorsexite and xenotime are the host minerals of REEs in the ores of this deposit. If the grade of these elements in these minerals is high, we can hope for exploration of these elements in this area. [60]

In another case study on Marvast Marvaz place in Yazd in the east and west, Morshedi et al. (2017) performed the following results. Data and samples were analysed from 53 wells in the eastern area; this anomaly in the south of Yazd city was used to model and find the potential of rare earth elements. In the Marvast region, the source rock is black shale monazite, which is found alternately with limestone and limestone sandstones and conglomerates in the form of scattered nodules in the shales. Examination of the distribution pattern of standardised rare earth elements to chondrite values indicates high compliance with the standard pattern of monazite. To investigate the geochemical distribution and concentration in the region, an interpolation map of the distribution of these elements was drawn. The most concentrations were related to light, intermediate and heavy elements, respectively. It was also proved by the intensity coefficient, including the ratio of the concentration of rare earth elements to light to heavy. In the next step, data clustering was performed at two levels of elements and samples, indicating four groups of elements based on light and weight (atomic and chemical structure) and four spatial zones based on promising areas, labelled as the fourth cluster. , Corresponds to the area of anomaly. Finally, the multivariate statistical method of principal component analysis was used to model the anomaly. [61]

2.6 Rare earth elements with coal and coal ash

In recent years, the reduction of familiar sources of rare earth elements in the world, such as carbonatites, has led to the beginning of exploration activities to provide primary sources of these elements in other fields. Recovery of rare earth elements from coal reserves as a by-product in many countries can help reduce the current raw material crisis. It can also be used to convert polluted coal into clean energy sources. Studies have shown that the concentration of these elements in coal ash is several times that of coal. Rare earth elements in coal ash are divided into three groups: heavy, medium and light. Among these, medium and heavy groups are more critical because their available resources are more limited. These elements accumulate in coal under four types of genetics and are 1- alluvial type, 2- tuff type, 3- infiltration type, and 4- hydrothermal type. The resulting hydrothermal reserves are more desirable in terms of grade and storage. By examining Iran's coal resources and comparing it with other countries in the world, Iran is richer in sources of rare earth elements in coal than China, the United States, etc. Paying attention to this issue can have a bright future in recovering these elements from coal ash in our country. [62]

According to the above points, extracting these elements from coal ash, which contains a significant amount of REE, should be considered. According to the study, the dissolution of elements in ash in an acidic environment depends on the content and formation of the ash. However, the amount of dissolved elements increases with increasing temperature and dissolution time. After the dissolution of REE elements in sulfuric acid, these elements' separation methods are the same as those used for processing common REE ores. [63]

The following results were obtained in a study on rare earth elements in coal conducted by Shahraz et al. (2014). In addition, the mineralogy was examined using the SEM technique. According to the data, the accumulation of some trace elements in Iran's coal reserves is much more than that of China, the United States, and the majority of the world's coal and its Clark quantity. In the commission area, the average accumulation of rare elements and the perspective index were 378.21 g / kg and 0.48 g, respectively. Also, the value of 16.35 ratio of light to heavy rare elements indicates enrichment in the group of light rare elements. The origin of the accumulation of these elements in the coalfield is of clastogen type and depends on the fall and leaching of pyroclastic materials, rich in rare light soil elements. Therefore, these precious metals can be recovered at different stages of coal deposit development (overburden, coal mining, coal combustion and after the completion of coal storage in these mines). [64]

In another case study by Memar et al. (2016), the following results were obtained by examining the coal zones of Iran. After sampling from different coal zones (raw coal and concentrate and waste from coal processing in coal washing factories), the sample was analysed by mass spectrometer (ICP-MASS) method of fifty-seven elements and the abundance of some rare elements. Rare and earthy were treated. Then, by interpreting the data obtained from the analysis of samples, rare and rare elements and determining their concentration and enrichment in the country's coal and the economics of their extraction were examined. By reviewing and analysing the results of the analysis, the Khomrud mine has the highest number of anomalies, with anomalies in 13 elements. Also, Mazino Tabas thermal coal with anomalies in 9 elements and Central Alborz region (underwater) with anomalies in 8 elements are in the following ranks regarding the number of anomalies in rare earth elements. [65]

2.7 Reserves with bauxite deposits

Jajarm bauxite deposit (northeast of Iran) is the largest diaspora bauxite deposit in Iran, which is located as a stratiform deposit between Elika and Shemshak formations. The bottom-up of this deposit is composed of four parts of lower kaolinite, shale bauxite, hard bauxite and upper kaolinite. Rare soil elements have been studied using correlation coefficients between these elements and other elements. In the normalised chondritic diagrams of rare earth elements in the challenging bauxite section, the elements (Ce) and (Eu), especially the element Ce), show different behaviour compared to other elements and show positive and somewhat negative anomalies, respectively. Show. This is a result of the existence of these elements with different capacities compared to other rare earth elements in the hard bauxite section so that Ce with a capacity of +4 and Eu with a capacity of +2 have entered the mineral structure. The La / Y ratio in the hard bauxite section also indicates the acidic conditions prevailing in this section of the deposit, due to which the rare earth elements may have been partially washed away and settled in the lower sections. [66]

Mineralogical and geochemical studies in the Jajarm bauxite deposit indicate that rare earth elements that have shown a positive correlation with phosphorus and iron in the lower kaolinite section have been absorbed by hematite and clay minerals. Nb, V, Cr, rare earth metals and phosphorus. From top to bottom, bauxite horizons have an irregular vertical distribution. Also, a comparison of the content of Jajarm bauxite with Chinese bauxite deposits shows that the amount of rare earth elements in Jajarm bauxite is higher. [67]

3. CONCLUSION & RECOMMENDATIONS

Considering that in different stages of exploration and extraction of a mine, comprehensive information from mineralogy and elemental analysis is continuously collected from different zones, attention and use of this information can be of great help in exploring rare earth elements in that area and surrounding areas. . In many mines, despite the high percentage of these elements due to lack of study and lack of sufficient information about them, these elements are directed to tailings dams.

Attention to rare earth elements and iron-apatite deposits is considered and recommended for more comprehensive studies in various iron mines in Iran. Also, since these elements are associated with phosphates, phosphate can be an excellent exploration guide in determining the exact location of these elements.

In bauxite deposits, these elements are absorbed by clay minerals and iron oxides, and their extraction is more manageable, so the presence of these elements in bauxite deposits is essential.

Since these elements have not received much attention in recent decades and are now essential sources, tailings dams in various mines, especially coal mines, can be rich sources of REE, so to study the percentage and amount of storage of these elements in these mines are recommended as additional studies in this section can be of great help in exploring these resources.

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Need for Composting of Household Waste at Community Level

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Abstract: With steeply increasing population and high rate of consumption, the household waste generated is also increasing. Lack of efficient management of waste, owing to growing pile of garbage leads to increase in heights of landfills, in which more than half of the waste comes from household and is biodegradable. In USA, around 27% of all solid waste comprising of food scraps and yard waste ends up in landfills [1]. Similarly, India generates around 62 million tonnes of waste annually with nearly 50% of total waste being organic and instead of being composted, it ends up in the landfills [2]. Landfills are not only eye soring sights, but they also amount to third biggest cause of greenhouse gas emissions in India [2]. This calls for need of composting household waste at community level to tackle the problem at the source of generation. This paper aims at identifying current practices for composting in India, and identify challenges faced by authorities and individuals while implementing composting initiatives. This paper seeks to find answers to the posed research questions revolving around composting challenges with a possible suggestion for implementing composting activities in schools, household complexes and community parks and gardens.

Keywords: community composting; household waste management; composting practices; composting in India; individual composting; composting by citizens; suggested composting practice

1. INTRODUCTION

Household waste management is a complex issue in countries like India and composting practice often seems to be a failure when it occurs at community level even when it needs least amount of technology and investment. The quantity of waste generated in households amounts to more than fifty percent of the waste found piled up in the landfills. The quantity of household waste keeps on increasing day by day in contrast to the waste management at the landfilling sites. One can even mistake the landfill site at Delhi, India to be a mountain rather than a huge heap of garbage with birds hurling above it. This unbelievable ugly sight itself clearly points towards the systematic failure in waste management both at individual as well as municipal levels. The landfill site in city like Delhi, India is just one example. All countries over the globe are currently facing huge issue with managing waste as the households continuously generate it. Composting seems like an effective method for household waste management. The composting method, if followed at community level, has the potential to eradicate the problems faced by labors directly involved in waste management and can also help the citizens become more aware about the high amount of household waste generation so that they can make conscious choices regarding their consumption habits.

This research paper is an attempt towards finding answers to the following questions:

1. What are the easy methods to implement for composting at individual levels?
2. Can these methods be used to compost in community level? Why or why not?
3. What challenges are faced by individuals while composting individually and collectively?
4. Can we mitigate these challenges through simplification of composting methods?
5. Suggestion for composting methods at community level.

Before getting into these mysterious questions, one should first know about composting.

1.1 What is Composting?

Composting is the process of decomposition in a controlled environment., i.e., the natural process of breakdown of organic waste materials and transform into a biologically balanced and humic substances that make brilliant soil alterations [3]. Compost is easier to manage and store, when compared to manure and other raw organic materials [3]. In composting, usually the microorganisms help in breaking down of the waste to formulate it into useable form known as compost. During composting, processes occur from beginning till end, i.e., till the compost is made as per Figure 1.

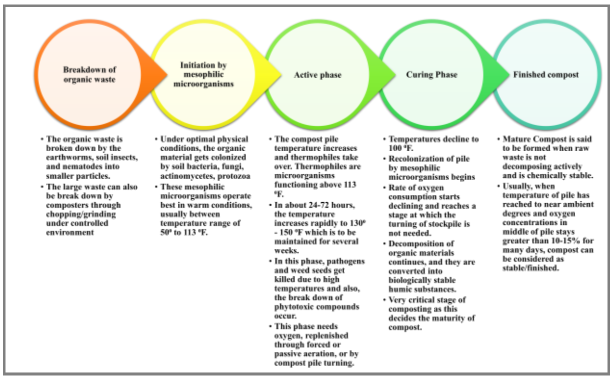

Figure 1. Process of composting and various stages [3]

1.2 What are various types of composting methods?

Composting methods can be divided into three main types depending on the decomposition process involved, i.e., aerobic composting, anaerobic composting, and vermicomposting. In aerobic composting method, as the name suggests, the composting of biodegradable waste occurs with the help of oxygen and the mixture needs regular turning. It produces a little amount of CO_2 along with other nutrients required by the plants. In anaerobic composting, the process happens in absence of oxygen due to which a foul odour is generated along with methane gas which is another source of greenhouse gas emissions like CO_2. In both these methods the composting happens due to bacteria whilst in vermicomposting, worms break down the biodegradable waste and produce compost. This method doesn't produce any odour.

Then depending on the method used for piling the biodegradable waste, composting methods can also be categorized as sheet composting, trench composting, cold-bin composting, and heap composting.

1.3 What are the benefits of compost?

The question about benefits of composting is like asking about benefits of food. But, keeping sarcasm apart, the compost is not only beneficial for providing nutrients back to soil, it also is a great way to manage biodegradable waste irrespective of its generation sources (restaurants, households, schools, cafes, industries, hospitals and so on). The compost serves as the final missing gear in a complete lifecycle for a biodegradable material. Take food for example. The soil we use to grow our food in is then returned back its nutrients in the form of compost as a gratitude. It may seem like philosophical talk but it's true and makes sense.

Composting is eco-friendly and has minimal effects on environment, except for the GHG emissions in form of CO_2 and CH_4 when the process is not properly controlled and supervised.

2. HISTORICAL BACKGROUND

During the 1930s, municipal solid waste management and disposal were least priority. There was few or even no formal management present to tackle the issue of waste [4]. Even though it has huge public health and environmental significance, it was not considered such between 1930 to 1940. Despite the objectionable elements and attributes, the open dump of waste was a common practice for waste disposal [4]. In some places, it is still practiced. But the discussion about current waste disposal practices will come a little later in the paper.

The publications dedicated to solid waste management were few until the 1960s, especially when literature for composting is concerned. Mostly it was found as project reports and articles in obscure journals or periodicals which were quite challenging to acquire. [4] In early 1970s, professional disinterest persisted until resource conservation, ecology and environmental quality started to get public attention [4]. Farming and Organic gardening were the major areas accounting for interest and activities in composting prior to 1970s [4].

If one were to look at the change in type of waste by comparing pre-industrial and post-industrial era, one could easily notice that the waste generated in pre-industrial era was less toxic, low in quantity and easily biodegradable even though waste management was a failure in both eras [5]. In Indus valley civilization, people used cotton clothing and the city of Mohenjo-Daro had houses with garbage chutes and Harappa city had toilets [5]. As the human population started increasing steeply, around 8000-9000 BC, waste dumps were established away from settlements to keep away wild animals, insects, and odours [5]. The Minoans used to cover waste with layers of soil and by 2100 BC, cities on the Crete Island had trunk sewers. The transition from nomadic communities towards settlement started initially around Neolithic revolution. [5] The first records of solid waste management were found in Athens, Greece during 500 BC and the first municipal dump was built in Athens for people to dispose off their solid waste [5]. Greek municipalities started town garbage dumps for discarding food trash, fecal matter, etc. in the 5th century BC [5]. The waste disposal was not treated like human health hazard until the authorities started to realize the connection between epidemics like plague with solid waste disposal methods. When in 1350s, approximately 25 million people were killed in span of five years owing to "The Black Plague", that was the time when Britain made a law to clean front yards mandatory but it was not taken seriously [5]. Britain was the first to introduce garbage men for solid waste collection as per historical references [5]. They were called 'rakers' because they used to rake up solid waste on weekly basis into a cart [5]. Then in the year 1551, the use of packaging was first recorded in Germany [5]. The use of and manufacturing of paper spreading from China to medieval Europe, developments in operation and dyeing of wool in 13th century, introduction of paper making techniques in England in 1310, invention of low-density polyethylene in 1942, etc. are just a few activities generating huge amount of waste which added more obstacles [5]. Heaps of waste was also a problem for Paris which was then removed by employing 800 carts as they were interfering with the city's defence [5]. Owing to the plague epidemic, the solid waste management became of utmost importance in Europe, but not in Asia and Africa, in spite of being colonized by Europeans [5].

The solid waste management was already taking a backseat owing to lack of laws and interests when the globe was hit with industrial revolution. As the production and evolution of new products started quickly, the manufacturing also increased due to industrial revolution [5]. It's natural that waste automatically increased as the market capacity increased. Now, the question comes to mind, if there were so much technological advances, then it might appear that waste management would also be efficient. Was the waste management in post-industrial era more efficient as compared to pre-industrial era? Let's take a look at it. As industrialization led to new and enhanced products, it also consequentially led to change in waste quantity and quality [5]. All over the globe, 'waste management' entered in many municipal acts [5]. This doesn't mean that implementation of waste management acts also dramatically changed for good. In fact, implementation was still inadequate because municipalities were not being supervised by any outside agency, no punishable law for officers in charge of enforcing the waste management acts, no laws for industries outside municipalities, to just name a few [5]. The industrial revolution made manufacturing cheaper which led to increased consumption and that led to more waste production.

The United Nations Conference held in Sweden in 1972 on Human Environment was a turning point for waste management [5]. Representatives of 113 nations attended UN's first international environmental conference [5].

In the 20th century, Plague caused widespread havoc in India and Vietnam with more than twenty-five thousand deaths. This forced Indian authorities to take extensive measures to manage solid waste [5]. The world population kept rising with the coming years and societies started wasting food more than ever especially in developed worlds [5]. Waste generation capabilities can also be linked to financial capacities per capita for every country. Higher the income per capita, higher consumption and hence, higher waste generation.

In all this chronological discussion about solid waste management, where did composting come in historical timeline? Composting has been a part of human life since the time of Neolithic period when human beings started settling instead of living a nomadic life. In the process, their habits shifted from hunting and gathering towards farming and breeding. [6] Waste pits came into common existence. The first waste pit was made using stones outside the houses in Sumerian cities about six thousand years ago [6]. These pits were used to store organic urban waste to be eventually used in agricultural fields [6]. In countries like India, China, South America and Japan, the early civilizations used to utilize residues from agriculture, animals, and humans as fertilizers due to intensive agriculture practices [6]. Traces of advanced systems being developed in Imperial Rome for urban waste management could be found. Periodic Urban waste collection, its disposal outside the town and application to agricultural soils eventually were done to preserve hygiene of the city. [6] One of the most accurate descriptions for composting could be found in the manuscripts of the thirteenth century which reported techniques of recovering fertility in depleted and arid soils, used by the Templars [6]. These descriptions included preparation of various materials for obtaining different types of compost for variety of crops, careful determination of ratios between wood and animal manure and moisture, reduction of moisture loss via evaporation by covering windrows with soil or branches, etc. [6] At the time when terms like soil chemistry and microbiology were unknown, the accuracy of these descriptive documents is rather fascinating. This depicts that the Templars' understanding of various aspects of soil biology, geology, basic elements of agronomy & soil fertility, and the art of composting is commendable. [6] Then came the advances in area of composting during the 20th century. It was in 1933 in India when first major advance was made by Sir Albert Howard in modern compost history. [6] He with his workers came up with a process by the name of "Indore process" which used animal manure initially but later stacked alternate layers of readily biodegradable materials (like human faces, straw, garbage, leaves, animal manure, stable waste and municipal refuse) on open ground [6]. The height of pile was kept at a meter and a half or compost was placed in less than one meter deep specially constructed pits [6]. This process used to take minimum six months during which compost piles was subjected to aerobic decomposition for a short while and anaerobic decomposition for the remaining time [6]. This Indore process was so widely used in India by many that the Indian Council of Agricultural Research even changed the name of this process to 'Bangalore process' after some improvements [6]. A significant improvement in this process was maintaining aerobic conditions by frequent turning [6]. The results of study conducted by Scott and others before World War II relating to agricultural sanitation in northern China revealed problems dealing with composting human wastes in rural areas [6]. Many researchers were studying the composting process and the effects of various elements like the type of waste used, time taken for decomposition, type of decomposition, etc. on the quality of compost in the twentieth century [6]. The mechanization efforts were happening in Europe while countries in China, India and Malaysia were refining the process [6]. The mechanization of composting led to many innovations, and these were mainly focusing on aesthetic improvement of composting process, time reduction for stabilization of compost and making it more economical. The designing for enclosed and mechanized processes was being applied in urban areas primarily. [6] For example, in Italy, the Beccari process composted material in an enclosed structure to avoid foul odours due to decomposition [6]. The innovations like Frazer process, Hardy digester, Earp-Thomas digester, Dano process, etc. are just a few to name [6]. The list of composting methods practiced in historical times in India, USA, London, or everywhere else in the globe is unending and even with modifications, one method doesn't seem to be fulfilling needs for everyone depending on the type of waste generated and geographical locations even though municipalities have been establishing demonstration facilities, waste management practices, and policies.

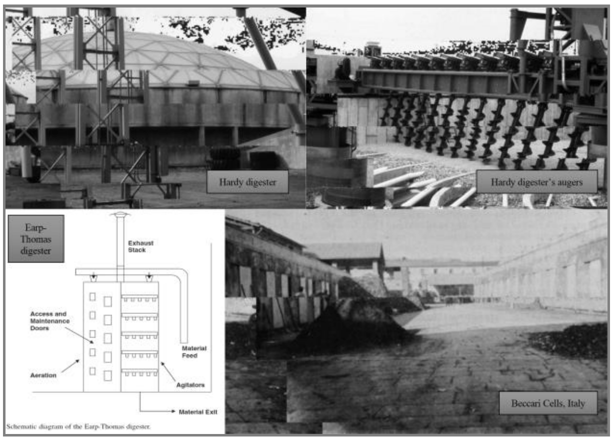

Figure 2. Innovations for composting methods [6]

3. STATISTICS ABOUT HOUSEHOLD WASTE AND LANDFILL SITUATION

As per World Bank report, an average person generates 0.74 kilogram of waste which varies between 0.11 to 4.54 kilograms. Globally, about two billion tonnes of municipal solid waste is generated, out of which 33% of total waste is not even managed safely in the environment. As we move towards 2050, the global waste is expected to grow by 69%. [7] In fact, countries in East Asia and pacific region generates about 23% of global waste with European and central Asian countries producing 20%, which makes them major contributor towards globally generated waste [7]. Food and green waste amount to largest proportion of globally generated waste and makes about 44% of total value at international level [7]. 40% of total global waste gets disposed in landfills, only 19% of total global waste undergoes recovery through composting (5.5%) and recycling (13.5%) and 33% of total waste is still dumped openly. This practice of open dumping is prevalent more in lower-income nations which do not have proper landfills. These statistical data and figures are more than enough to highlight the potential of managing organic waste through composting. [7]

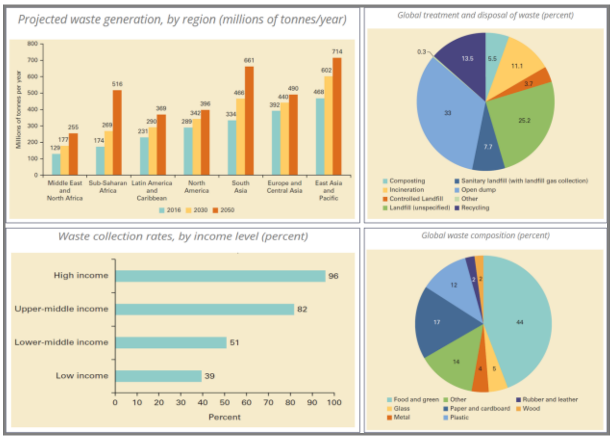

Figure 3. Statistics on global waste generated, collected, and dumped [7]

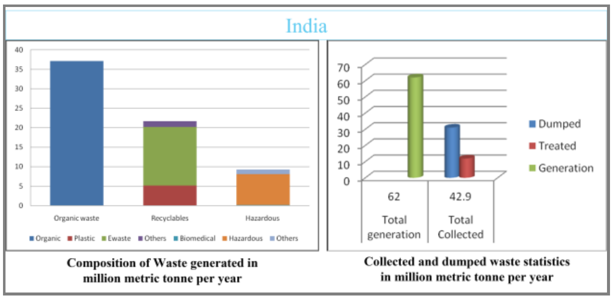

Figure 4. Statistics for waste generated, collected, and dumped in India [2]

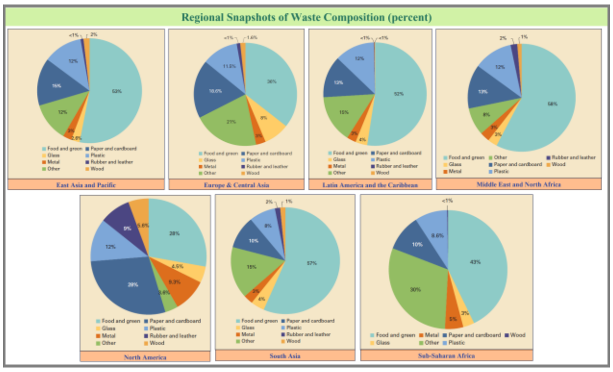

Figure 5. Statistical data for Global waste composition at regional level [7]

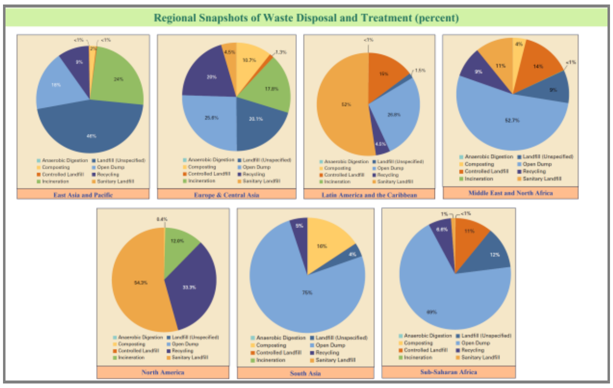

Figure 6. Data on Global waste disposal and treatment at regional level [7]

4. LITERATURE REVIEW

There are many composting techniques already used by people all around the globe from converting their organic waste matter into useable compost. The process may be aerobic, anaerobic or vermicomposting. But the technique for composting involves the modifications performed from collection of organic waste in certain manner to handling the various stages (mesophilic, thermophilic, cooling, curing) till finished compost is formed. There are conventional composting techniques along with the novel ones. Conventional ones include Windrow composting, in-vessel composting, aerated static pile composting to name a few. Windrow composting involves decomposition of piles of waste with aeration and simultaneous turning [8]. These are economical due to no heavy mechanical tool requirement for aeration. Depending on the type of waste and equipment used for flipping, the height of windrow varies. If the tool is small like a ladle, keeping height smaller makes logical sense while with a big tool like raking stick, the pile height can be elevated. In in-vessel composting, as the name suggests, the organic waste is kept in a closed container or vessel in controlled conditions. This composting system involves agitated bags and rotating drums to enhance decomposition process and boost the rapid composting through mechanical agitation and instinctive rotation [8]. In vermicomposting, the biodegradable waste is decomposed with the help of earthworms of different species like *Eisenia foetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* [8].

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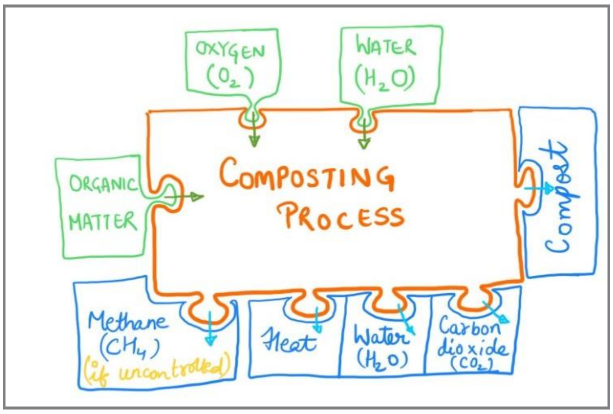

Figure 7. Composting Process

The aerated static pile composting involves decomposition of organic waste for over a month without any physical activity in the pile. For aeration, perforated pipes are used, and the waste piles can be kept in covered, open, windrow, or semi-covered form. This process is critically dependent on rate of aeration which produces temperature difference in the pile vertically [8]. In aerobic composting, the decomposition happens in presence of air at specific temperature and pH range as a result of which the micro-organisms convert the organic waste into a bio-fertilizer loaded with nutrients and optimization of the aeration rate can help with the odour problem [8]. Households usually don't prefer anaerobic composting due to methane production which leads to a foul odour and also contributes towards greenhouse gas emissions. On the other hand, vermicomposting and aerobic composting seems to be welcomed by households considering the least amount of technology and money involved. But they too have their challenges.

There is also a technique known as co-composting in which the augmentation of composting is done with the help of a mixture of two different waste [8]. It provides a best solution for food waste processing as food waste and waste substrates (like wooden chips, rice bran, rice husks, chopped hay, sawdust, wheat straw, and other similar organic waste) can be combined together to maintain favorable ratio of carbon & nitrogen, moisture, void spaces, and nitrogen content [8]. Even the lower pH of food waste can be managed by addition of sodium acetate in waste mixture [8]. Co-composting activities can use feedstocks, like poultry litter, pig manure, etc. as well [8].

Another novel composting technique is with the help of arthropods. Arthropods are invertebrate species of animals with an exoskeleton, paired jointed appendages, and a segmented body. In this composting method, an essential arthropod species is enticed at various decomposition stages and all these arthropods complete their life cycle during the process of composting [8]. These species are helpful for boosting the development of consentient species, and arthropods like black soldier fly larvae and millipedes have been used for composting of a variety of biodegradable waste [8].

There are various challenges during composting process. First barrier comes in the form of confused minds of beginners who have just started composting. For composting household waste, public motivation is seemed to be low for using barrels and separating the waste at source [9]. The public also seemed to be confused over what to separate along with cultural stigma attached with touching waste [9]. The size of the plots available for composting pits also restricts the composting activities. The best way to ensure efficiency in composting activities lies in separating the household waste at the source of generation, i.e., segregating the organic waste at home itself instead of doing it later at a landfill where, by the time the segregation starts, majority of the waste has gone into uncontrolled decomposition state which can do more harm to the segregator. This calls for cooperation between households, waste collector and the composting organization if the composting is being done at a large facility [9]. The waste collection fee charged from residents also make them concerned about the usage of the money and the income generated from the sale of the compost [9]. It has been observed that raising motivation through environmental cause or economic incentive is also very difficult to achieve when it comes to composting household waste [9]. Since the composters do not reap higher profits from composting plants as compared to other businesses, dumping of waste has become highly unregulated in countries with low-income due to low motivation from municipalities as well [9]. Due to lack of necessary capital (like buying or renting land) and unawareness about the technology, process or potential markets, the urban poor have also shown least interest in the composting activities [9]. Biodegradable waste, that decomposes slowly or needs shredding using machinery, often requires money, time and equipment and this also pose as a challenge for composting at regional levels [9]. High short-term costs associated with switching from industrial fertilizers to bio-fertilizers produced through composting also acts as a barrier for farmers [9]. Another major challenge occurs when the composting plants target the employment creation for the poor but the improvement in labour conditions is not guaranteed [9]. For example, workers may not get equal respect in society even if they work at composting plant or facility due to the stigma attached with touching waste. Increased waste means need for more land for composting as composting cannot happen in a day, but the waste generation occurs without any stop. Shortage of land space for community level composting also is an issue in the process. It is also a challenge to decide the effect certain type of compost can have on the soil or plants it is utilized for and this also forms a dilemma and hesitation in people's mind for using compost. Community level composting calls for proper management of compost bins to ensure hygienic conditions. And since composting is not the only thing on people's mind, various composting initiatives start but are not supervised or managed properly and this leads to more environmental hazard near the compost pile. Imagine if the temperature of compost pile doesn't reach to certain degrees and instead of killing the pathogens naturally, it starts to become a breeding ground for infections.

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So, the question arises what can be done to mitigate these challenges? For beginning, waste segregation is required at household levels and easy composting activities should be initiated at community levels and decentralization of waste management is required. When the waste generation is not centralized, the waste treatment can also not be successful through centralization. A lot of interventions are necessary for increasing composting of waste. Some of them include policies for waste segregation, bulk waste producers and responsibility distribution based on amount of waste generated individually. There is also a need to charge waste collection fee based on family incomes as it is observed that the increase in income leads to rise in consumption and consequentially increase in waste generation. Incentivizing the poor or low-income groups for composting is also a great step towards increasing motivation. Educational awareness campaigns for behavioral changes through schools is also a good approach.

5. SPECIAL INTERVIEW

A telephonic interview was conducted by author of this paper in the year 2021 with the purpose of sharing citizen's experience of composting process to link the scientific community and the citizens to start a dialogue needed to emphasize community-level composting. Refer Figure 8 & Figure 9 for the details of the interview.

Figure 8. Telephonic Interview Part-A

Excerpts from the Interview

Q1. When did you start composting?
A1. I started composting three years ago.

Q2. What motivated you to start composting?
A2. I have always been inclined to gardening since my childhood, but never tried it. Three years ago, I saw this advertisement about a course on home-waste composting being organized near my home and I enrolled for it. After learning the method, I started composting at home. To be able to provide nutrition to soil and plants through my kitchen waste motivated me to do this.

Q3. How often do you make compost? How much time does it take to make compost?
A3. I make compost three times a year. The total process takes 4 months from collecting waste to formation of compost. It takes 1 month for collection of waste and 3 months for compost formation.

Q4. How much compost are you able to make?
A4. I use earthen pot as compost bin and can make 5-6kg of compost using the pot of 10L capacity.

Q5. What type of waste do you use?
A5. I use all type of food waste generated in the kitchen including peels of vegetables, fruits, tea leaves. I do not use cooked food, or peels of onions and garlic.

Q6. What's the process like? What do you do for the odour generated in the process of composting?
A6. I take an earthen pot to use as compost bin. I put my kitchen waste everyday into the pot along with cocopeat. The quantity of cocopeat used is half the quantity of kitchen waste. It takes one month for the pot to be completely full of waste and cocopeat. While collecting waste, I keep stirring the mixture so that it doesn't form a block that cannot be stirred later on. After collection is over in a month, I keep the pot covered with a sieve or cloth on the roof in ventilated area to avoid the smell coming inside house. In about 3 more months, the compost is completely ready to be used in the garden.

Q7. What do you use this compost for?
A7. I use this compost as natural fertilizer for my plants. I also use this fertilizer while conducting plantation drives in my community.

Q8. What challenges did you face in the beginning? Did you get support from family or neighbors?
A8. There were a few challenges that I faced. Firstly, in the beginning, the compost used to become a thick block and it was difficult to stir it. But then I started stirring the mixture every time while putting the waste in the pot and then it became easier to stir. There's also a lot of odor that comes from the pot while decomposition is in progress. So, I couldn't keep it outside or inside the house. I chose a place on the terrace which is open and ventilated. As far as my family is concerned, they didn't actively support me, but they didn't stop me either. Now, they even recommend me when people have doubts about composting. They also respect my passion.
I have also inspired my neighbours and some of them have even started growing their own vegetables using the compost in their backyards and terrace. In the beginning, neighbours used to criticize it as it is a lot of hard work but now, they are all supportive and eager to learn more.

Q9. How much does it cost you?
A9. Honestly, it doesn't cost a dime to make compost at home. Everything from pot, waste, wooden stirrer can be used without buying it. Earthen pot and plantation pots are the only thing that cost money and that too is less than 500 INR.

Q10. How does your gardener feel about it?
A10. Earlier he used to feel threatened as it posed a threat to his job. But when I gave him the plants, I grew using the compost and seeds, he was happy. He also is elated that I am managing my own household waste.

Q11. Have you tried collaborating with your gardener by giving him the extra compost left with you?
A11. No, I haven't till now. But I like this idea. I usually have large amount of compost and not able to use all of it. So, I use it to plant seeds and give those plants as gifts to people around me. But this sounds like a great initiative. Next time, when I see him, I will ask his thoughts about this.

Figure 9. Telephonic Interview Part-B

6. SUGGESTED COMPOSTING METHOD AT COMMUNITY LEVEL

Figure 10 shows a sample area of a residential complex with a government building and district park on its side, all situated in the west district of Delhi, capital of India. This is just taken as a sample area to put forward an idea for composting at community level and using the compost for the benefit of the surroundings. Figure 11 depicts the steps that can be taken to implement this idea. The idea is to utilize the roofs of the apartments to install compost bins and every house in the residential complex contribute their biodegradable kitchen waste generated every day to these roof bins. Then the process of composting can take place with residents taking turns for flipping the waste every once a while till the compost bin is full and cannot accommodate any more waste. Then the organic mixture is left to decompose till the final compost is ready with frequent turning of waste in bin for proper aeration. Then final compost can then be used with the help of local gardeners to provide soil nutrients to areas with existing trees and plants. It can also be used for soil amendment in the adjoining district park and as biofertilizer for growing new plants to increase the green patch in the region. This, of course, cannot happen without proper education, community proactiveness, coordination between gardeners and residents and needs to be supervised by any person who has been doing composting or a person who is a compost expert.

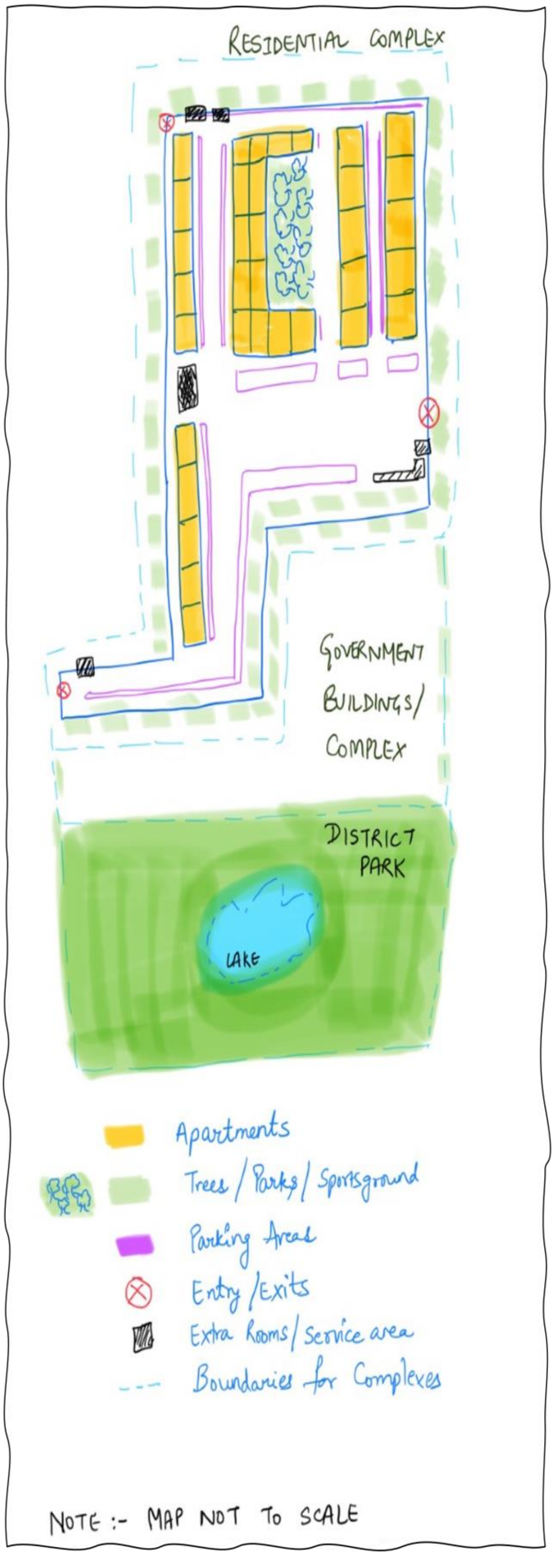

Figure 10. Community Map for suggested idea

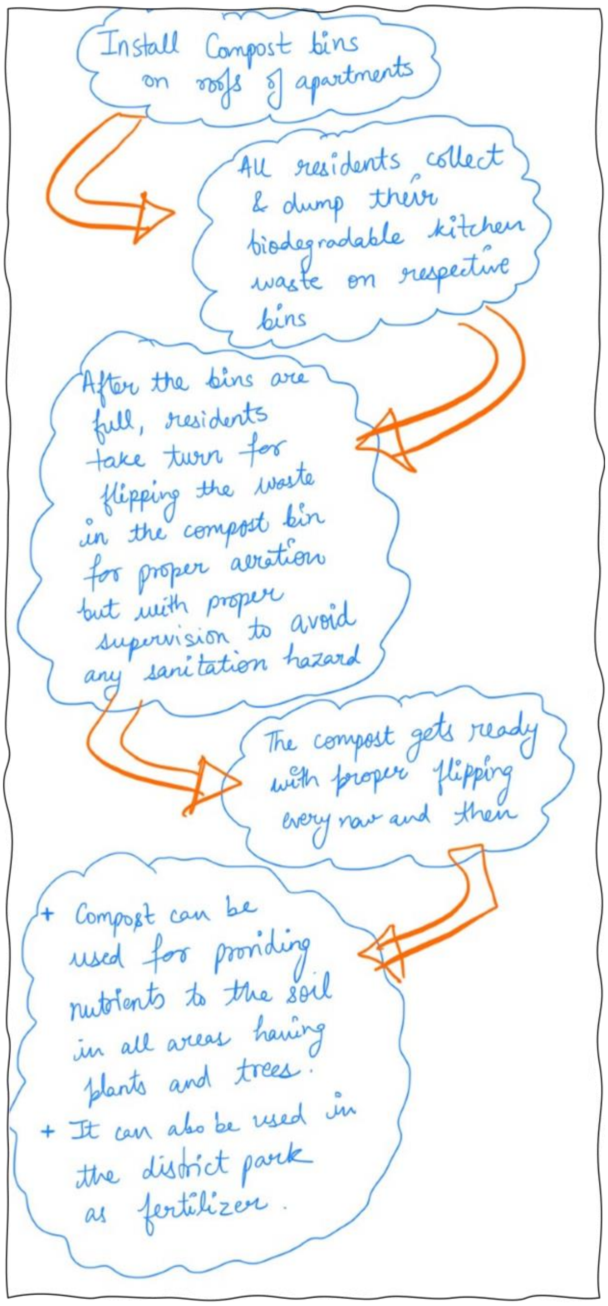

Figure 11. Community composting steps

7. DISCUSSION & CONCLUSION

Composting has been practiced since ages and being a biological decomposition process, it has its advantages and limitations. Considering the data collected by World Bank on waste generation, composition, disposal, and treatment, it is clear that organic waste forms a major portion of the waste and composting organic waste seems to be a good bet for solving the crisis of increasing piles of waste in landfills. It becomes clear that every individual can follow composting methods that require minimum cost, time and technological investments and still contribute towards waste management by dealing with waste at the source. Local solutions and initiatives can help better as compared to a centralized approach and composting activities can be modified based on the region. This also makes people aware of their consumption habits and helps in bringing behavioral changes. Incentivizing composting initiatives can also motivate communities to cooperate and start composting. Citizen engagement and participation is key in composting and should be kept in mind while making policies. Composting, even with its list of challenges, has the potential to kill two birds with one stone: the problem of waste management and greenhouse emissions from the open dumps or landfills.

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Characterization of the Drilling Mud Adapted to the Geological Formations of the Agadem Oil Field, Termit basin (Southeastern Niger): Case of the Dibella Well

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Abstract: The objective of this study is to characterize the drilling mud adapted to the geological formations of the Agadem oil field (Niger). During the drilling process, the mud is monitored and adjusted regularly according to the instantaneous logging data. Thus, the typologies of drilling mud and their physicochemical and rheological properties at the level of each phase of drilling were determined in the laboratory of the site during the realization of the Dibella well. Two (2) types of mud (Pre-hydrated bentonite (PHB) and polymer) were used during the drilling of the Dibella well. The PHB mud, used from 0 to 800m depth, is characterized by a variable density depending on the lithology, a MARSH viscosity of 60 to 75 seconds and a pH between 8 and 9. The polymer mud, used between 800 and 2680 m, is characterized by an equally variable density, a MARSH viscosity of 55 to 60 seconds, a plastic viscosity of 10 to 20 mPa.S, a yield point between 2 and 10 Pa, an apparent viscosity of 3 to 5 mPa.S, a Gel strenght ($G_{10''}/G_{10'}$) of 1 to 4/2 to 10 Pa and a pH, always between 8 and 9. These parameters, which allowed the Dibella drilling to be carried out in an optimal way, can be used as a guide for the realization of new wells in the study area.

Keywords: Agadem oil field, Dibella well, Pre-Hydrated Bentonite mud, Polymer mud, Physicochemical and rheological properties.

1. INTRODUCTION

The Agadem oil field is an integral part of the Termit basin, located in the southeastern part of Niger. Important hydrocarbon deposits have been identified in the said basin where the sedimentary thickness would reach more than 4000m. The exploitation of these deposits necessarily involves drilling. Drilling is a complex activity whose success depends mainly on the quality of the drilling mud [1,2]. The choice of the mud is essentially linked to the nature of the ground to be crossed and the depth to be reached. The objective of this study is to determine the characteristics of the different muds used during the drilling of the Dibella well on the Agadem oil block. Thus, during the execution of the drilling, the mud is regularly monitored and adjusted according to the data of the instantaneous logging (parameters of the drilling machine) [3]. These parameters indicate the stability or not of the well walls, the water-bearing, porous, impermeable, clay or sandy zones. When crossing these zones, the drilling fluid is adjusted (addition of water, bentonite, soda ash or other products) to ensure the safe progress of the drilling [4]. Also, at each stage of modification of the mud, its characteristics are determined in order to elaborate a drilling mud model adapted to the Agadem oil field. The parameters characterizing the mud, determined in the site laboratory, concern the pH, viscosity, density and rheological properties [5]. Thus, the characteristics of the mud according to the type of formation crossed during the drilling of the Dibella well on the Agadem block, were established. These characteristics can be used as a guide for new drilling in the study area.

2. GEOLOGICAL CONTEXT

The Agadem Oil Block (Figure 1) occupies the hinge part of the Termit Basin, belonging to the large Eastern Niger Basin (Chad Basin). The Termit is characterized by a graben system controlled by a network of NS, NNW-SSE and NW-SE oriented faults [6]. The thickness of the sediments in these trenches can reach more than 4000 m, where significant accumulations of hydrocarbons have been demonstrated [7]. The age of the sediments identified in the grabens varies from early Cretaceous to Neogene. The existence of older series (Jurassic-Paleozoic) cannot be excluded [6].

Exploration drilling has discovered significant oil and gas reserves in the Termit Basin. These reserves are generally contained in the reservoirs of the Yogou formation in the Agadem block. The lithostratigraphic column below (Table 1) summarizes the succession of geological formations encountered on the Agadem block, their ages, their depths as well as their lithological descriptions. This column was established on the basis of the geological data acquired from the wells already drilled and the seismic profiles carried out.

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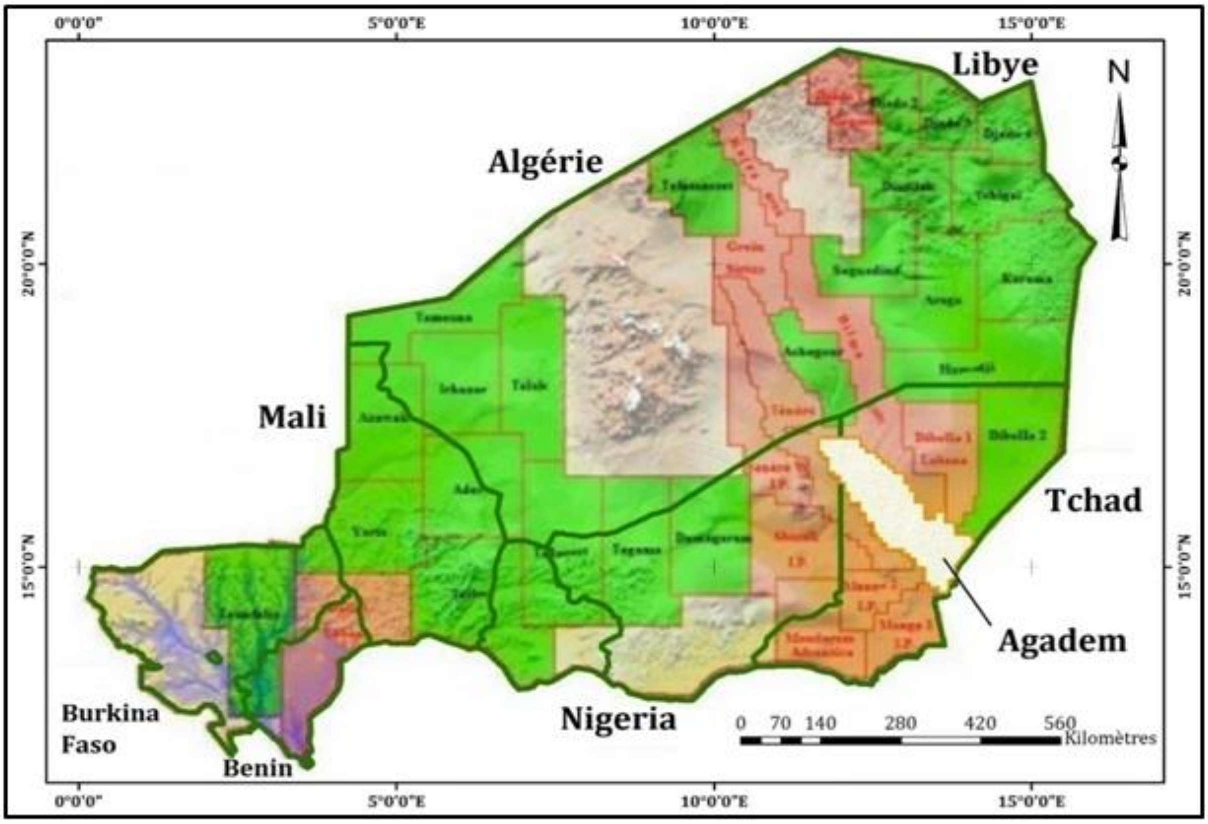

Figure 1. Location of the Agadem oil block [8]

The sedimentary filling of the Termit basin and its tectonic evolution are summarized as follows [9]:

- An initial rifting phase from the Aptian to the near Cenomanian constituted the first filling of the basin with fluvio-lacustrine shale.
- Another phase called thermal subsidence from the end of the Cenomanian to the Maastrichtian fills the basin with marine shales associated with striated sandstones and massive fluvial sandstones:
  • Deposition of a thick marine schistose series, slightly calcareous, called "Donga Clay" then newly defined "Fachi Clay" in relation with the general transgression towards the end of the Cretaceous (Cenomanian to Santonian),
  • During the decrease of the marine activity and as a result of the tectonic phase induced by the collision of the African and European plates there was first deposition of a thick layer of alternating shale and sandstone "Yogou Series" in the Campanian and then a thick layer of massive fluvial sandstones "Madama sandstone" in the Maastrichtian and after a complete transient uplift.
- Paleogene and Neogene tectonic phase :
  • Tertiary formation consisting of alternating fluvio-lacustrine shales and sand "Sokor Alternations" and then lacustrine shales "Sokor Shales" during the Paleo-Eocene,
  • Lake shales with small proportions of sandstone in the lower part of the "Oligocene Alternation" and "Oligocene Clay",
  • The aeolian sandstones are formed by fluvio-lacustrine and sandy shale series constituting the "recent formation" dated from the Pliocene half.

Table 1. Prognosis of the stratigraphy of the Dibella Well [9].

Age	Geological division	Approximate depth	Lithological description
Quaternary **Miocene**	Recent formation	600	Unconsolidated sand with occasional horizons of shallow lower section clay, fine to coarse grained sand and sandstone and gravel. Mainly quartz and some feldspar occasionally variegated by clay.

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Oligocene	Sokor claystone	1256	Claystone
	Medium velocity claysttone	1322	Claystone
Paleo-Eocene	Sokor sandy alternance	1990	Intercalation of sandstone and claystone
Cretaceous	Madama	2409	Solid sandstone
	Yogou	2680	Claystone with sandstone intercalation
Total depth		2680	

3. DIBEILLA WELL MUD PROGRAM

The mud program for the Dibella well is closely related to the different formations to be drilled, the environmental and economic constraints and the possibilities of supplying the products of its preparation on site [8]. To develop this program (Table 2), data from previously drilled wells in the Agadem oil field and seismic data were used. Drilling mud is used in drilling to perform various roles.

3.1 Definition of drilling mud

A drilling fluid or drilling mud is a system composed of different combinations of liquids (water, oil), gases (air or natural gas) containing in suspension a solid phase (clay, cuttings, cements). It's a non-Newtonian fluid, viscous or viscoelastic, most often thixotropic.

3.2 Roles of the drilling mud

Mud plays a crucial role in drilling in general and particularly in oil drilling [1,10]. The drilling mud is in continuous circulation throughout the drilling process, both in the well and at the surface (Figure 2). It is injected from the inside of the drill pipe to the tool. Then, it goes up through the annular space loaded with cuttings formed at the face. At the exit of the shaft, it undergoes various treatments (sieving, dilution, addition of product, etc.) in order to eliminate the transported cuttings and to readjust its physicochemical and rheological characteristics in order to ensure its proper functions [11]. In a non-exhaustive way, the following roles are recognized for drilling mud [1,10]:

- Cleaning of the well,
- Keeping the cuttings in suspension,
- Sedimentation of cuttings on the surface,
- Cooling and lubrication of the tool and the shank train,
- Prevention of cavitation and tightening of the well walls,
- Consolidation and reduction of the permeability of the well walls,
- Prevention of water, gas and oil spills,
- Increased speed of travel,
- Tool drive,
- Reduction of the apparent weight of the drilling equipment,
- Provide information on the survey.

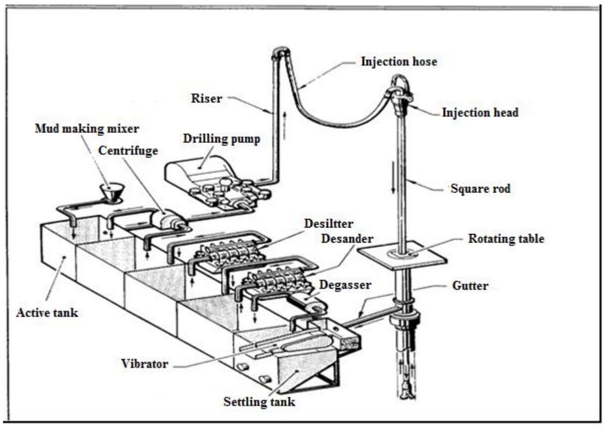

Figure 2: Drilling mud circuit [2]

3.3 Pre-Hydrated-Bentonite (PHB) mud

The PHB mud is planned for phases 1 and 2 of drilling for depths ranging from 0 to 800m. During these phases, the expected formations to be crossed are mainly sand and clay. This mud will consolidate the well's surroundings and ensure the continuity of the drilling in complete safety.

3.4 Polymer mud

Polymer mud is used during the 3rd drilling phase. This phase is crucial because it involves challenges that need to be addressed, such as the risk of gas ingress, high pressures on the hole walls and certain technical failures. At this stage, a polymer mud system will be prepared, whose characteristics must be regularly checked.

Table 2. Dibeilla well drilling mud program [8]

Hole diameter	Depth	Mud system	Mud density
17 1/2"	0-800m	PHB mud	1.03-1.05 g/cc
12 1/4"	800–2680m	Polymer mud	1.05-1.15 g/cc

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4. MATERIALS AND METHODS

4.1 Drilling mud preparation

Several types of mud are needed to carry out drilling on the Agadem block. These drilling are prepared in tanks erected on the site (Figure 3).

Figure 3. Mud tank used on the Dibella well site

4.1.1 Preparation of the PHB (Pre-Hydrated Bentonite) mud

Pre-hydrated bentonite mud is prepared using water, bentonite and sodium carbonate (Soda Ash). Other minor products, such as caustic soda and LCM (Lost Circulation Materials) are combined in the mixture.

Bentonite is a viscosifier and Ash soda is used to hydrate the clays and remove Cu^{2+} ions. The mixing of these products must take at least 16 hours before the drilling operation begins. The dosages of these products are recorded in Table 3 below.

Table 3. The formulation of PHB (Pre-Hydrated Bentonite) drilling fluid

Chemical	Function	Dosage (Kg/m^3)
Bentonite	Viscosifier	60-90
Soda Ash	Clay hydration and eliminate Ca^{2+}	2.0-3.0

4.1.2 Polymer mud preparation products

The polymer mud is composed of bentonite and products controlling the viscosity, density, pH and gel of the drlling mud (PAC-L, NPAN, KPAM, XCD, PAC-R and NFC). The dosages of these products and their functions within the mud are shown in Table 4 below.

Table 4. Formulation of polymer drilling fluid system

Chemical	Function	Dosage (kg/m^3)	Remarks
Bentonite	Viscosifier	25-40	
PAC-L	FL control agent	3-8	Can be replaced by NFC-1 or used together, total dosage is 3-8 kg/m^3
NPAN	Thinner/FL controller	3-6	Also can inhibit formation clay dispersing
KPAM	Encapulater/Viscosifier	2-6	High molecule weight polymer
XCD	Gelling agent	1-3	For choice, increase viscosity
PAC-R	Viscosifier/FL	1-3	For choice, increase viscosity
NFC	FL control agent	3-8	Replaced PAC-LV

4.2 Monitoring and determination of the physicochemical parameters of the mud

4.2.1 Monitoring of the mud physicochemical parameters

The monitoring of the physicochemical parameters is done through tests carried out at the site laboratory. On site, it is essential to control the characteristics of the drilling mud at regular intervals for any mud system used.

- The first check to be made is the determination of the chemical nature of the water (concentration of magnesium or calcium ions), which will make it possible to know the quantity of Soda Ash to be added to eliminate them.
- During the drilling process, care must be taken to ensure that the characteristics of the mud allow the consolidation of the well walls (avoid friction due to GEL, yield point and plastic viscosity) and control the infiltration of the drilling fluid (when porosity and permeability are high). These two controls help to maintain the stability of the well.
- Then, the mud must be cleaned of all the drilled solids that could affect the physicochemical parameters (viscosity, density and pH), using specific instruments

in the mud circuit (decanter, desander, desilter, degasser, etc.).

4.2.2 *Hydrogen Potential (pH) measurement*

The Hydrogen Potential of the drilling mud is measured on site with a pH-meter.

4.2.3 *Fluid Viscosity (FV) or MARSH viscosity Measurement*

MARSH viscosity is measured by measuring the time in seconds that a certain amount of mud takes to flow through the nozzle of a standard funnel. The mud flows into a graduated cup. The procedure consists of:

- Take the MARSH funnel and close the nozzle with finger,
- Take mud from the gutter and pour it over the funnel screen until the mud level reaches the surface of the screen (corresponding to a volume of 1500 cm^3),
- Hold the funnel by the side handle, start a stopwatch and let the mud flow into the measuring cup,
- Stop the timer when the mud level reaches 946 cm^3 (1/4 gallon in the bucket),
- The number of seconds read on the stopwatch represents the MARSH viscosity of the mud.

Figure 4. Measurement of mud viscosity using a MARSH Funnel

4.2.4 *Measurement of the density or Volumic Mass (MV) of the mud*

The measured density corresponds to the volumic mass. The measurement procedure consists of the following steps:

- Fill the cup with measuring mud,
- Put on the cover and drain off the excess mud that comes out through the central hole in the cover provided for this purpose,
- Clean with water and dry, taking care to keep the hole in the cover permanently blocked,
- Place the flail knives in the knife holder on the base,
- Move the cursor until the flail is horizontal. This horizontality must be checked with the spirit level located above the knives,
- Read the density directly on the arm of the flail, at the right of the cursor position.

Figure 5: Density measurement of the mudwith a densimeter

4.2.5 *Rheological properties tests (PV, YP, AV and Gel Strenght)*

To test the rheological properties of the mud, a sample of smud is taken and tested in situ at the site laboratory. It is important to avoid the drop in temperature of the mud, which can lead to erroneous results. The device used is the "six-speed viscometer", which as its name indicates, has six speeds expressed in revolutions per minute (600-300 / 200-100/ 6-3). The test procedure is as follows:

- Pour the mud into the cylinder of the machine.
- Make the level of the mud in the cylinder coincide with that of the six-speed rotor by raising the plate on which the mud is placed until it reaches the level marker ring (of the six-speed).
- Hold the cylinder containing the mud with the plate fixing screw.
- Run the motor of the machine at high speeds (600-300 rpm) and record the readings on the "six-speed" chart or counter.
- Run the motor at intermediate speeds (200-100 rpm), also recording the readings.
- Run the motor at low speeds (6-3 rpm), always reporting the readings.

The velocity ranges and reported values will be used to calculate Plastic Viscosity (PV), Yield Point (YP), Apparent Viscosity (AV) and Gel Strenght ($G_{10''}/G_{10'}$) according to the following Bingham calculation model:

PV= (value of 600 rpm) - (value of 300 rpm) in milli-pascal second (mPa.s).

YP = 2(value of 300 rpm) - (value of 600 rpm)/2 in Pascal (Pa).

AV= (values of 600 rpm)/2 in mPa.s.

The Gel Strenght is determined in 10 seconds ($G_{10''}$) and 10 minutes ($G_{10'}$) as follows:

For 10 seconds, the procedure is as follows:

- Run the motor at 600 rpm for 10 seconds and stop.
- Observe a 10-second pause during which the gearshift lever is returned to the low gear level.
- Select the speed of 3 rpm and report the maximum value read.
- Divide the value obtained by two to get the Gel strenght in 10 seconds ($G_{10''}$).

For 10 minutes:

- The procedure is the same as before, except that the pause lasts 10 minutes instead of 10 seconds.
- The value read will also be divided by two to get the Gel strenght in 10 minutes ($G_{10'}$).

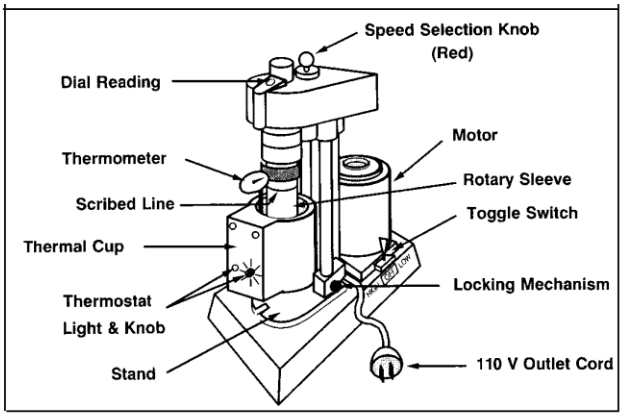

Figure 6. Six-speed viscometer [8]

5. RESULTS AND DISCUSSION

Two (2) types of mud were used in this study: the Pre-Hydrate Bentonite (PHB) and the polymer drilling fluid.

5.1 Characterization of the PHB drilling fluid

The PHB drilling fluid is used between 0 and 800m depth, in unconsolidated sand and clay formations. The results of the analyses carried out on this mud are recorded in Table 6.

Table 5. PHB drilling fluid properties

MV g/cm³	FV sec	PV mPa.S	YP Pa	AV mPa.S	$G_{10''}/G_{10'}$ Pa	pH
As designed	60-75	-	-	-	-	8-9

Pre-Hydrated bentonite (PHB) mud is characterized by three (3) physicochemical properties: density (MV), viscosity (FV) and Hydrogen Potential (pH).

- The density is not specified (as designed) because it's variable at any time of drilling. It's very sensitive to changes in lithology or to the presence of fluids or pressures in the formations. This mud (PHB) has been used for recent, very poorly consolidated formations; this requires a density high enough to traverse safely [12]. In addition, a very dense mud is required to cross water tables.
- Fluid viscosity (FV) can be defined as all the phenomena of resistance to the movement of a fluid for a flow with or without turbulence. Viscosity reduces the freedom of flow of a fluid and dissipates its energy. Viscosity is one of the most important parameters of the mud because it's through viscosity that the mud performs the following functions [13]:
  • Sedimentation of fine cuttings on the surface,
  • Keeping the cuttings in suspension,
  • Cleaning the well,
  • Increasing the speed of travel,
  • Cooling and lubrication of the drilling tool and drill string.
  Very low viscosities are a favourable factor for the penetration of the drilling tool, but they do not favour the maintenance of cuttings in suspension and their evacuation on the surface [13]. In addition, when formations are poorly consolidated, high viscosity is necessary to better evacuate them. Hence the high viscosities (60 to 75 seconds) are measured for the recent formation which is made up of unconsolidated sand.
- The Hydrogen Potential (pH), characterizes the acidity or basicity of the mud. A mud can be acidic or basic depending on the nature of the formations or their content. Thus, as the geological formations of the Agadem oil field are more or less basic, the pH of the prepared mud must always be greater than or equal to 7 to avoid any acid-base reaction.

5.2 Characterization of the Polymer drilling fluid

The polymer drilling fluid is used between 800 and 2680m depth, in alternating sandstone and claystone, indurated. The results of the analyses carried out on this mud are recorded in Table 6.

Table 6. Polymer drilling fluid properties

MV g/cm³	FV sec	PV mPa.S	YP Pa	AV mPa.S	$G_{10''}/G_{10'}$ Pa	pH
As designed	55-60	10-20	2-10	3-5	1-4/2-10	8-9

The polymer mud is characterized by physicochemical properties (density (MV), viscosity (FV) and Hydrogen Potential (pH)) and rheological properties (Plastic Viscosity (PV), Yield Point (YP), Apparent Viscosity and Gel Strenght ($G_{10''}/G_{10'}$)).

- The density (density) is not as specified (as designed) for polymer mud because it is variable at any time of drilling for its great sensitivity to changes in lithology, presence of fluids or pressures of formations [14]. At great depths, it also allows to control the pressure of the formations and gases, the invasion or the overflow of fluids in the well. This gives the well a great stability.

- The Fluid Viscosity (FV) is relatively low (55 to 60 seconds) compared to the PHB mud. This is due to the presence of consolidated formations in this portion of the borehole.
- The Plastic Viscosity (PV) of the mud is a state of viscoplasticity corresponding to a perfect solid behavior at low stresses and a viscous fluid behavior above a threshold stress [15]. This property is very useful for the transport and disposal of cuttings [16]. The PV has medium to high values (10 to 20 mPa.S) in the polymer mud. These values are relative to the greater or lesser depths of the Dibella well where this mud was used, since the greater the depth, the higher the value of plastic viscosity should be.
- The Yield Point (YP) or fluid pressure allows the mud to ensure the stability of the walls of the hole and to fight against the eruption of gas or hydrocarbons in the well [12,17]. This is the drilling mud pressure. This pressure must be high enough to fight against the pressures outside the well. At a depth of more than 2000 m, the pressure of the geological formations around the well is very high, as is the pressure of the fluids in the vicinity of the hole. The Yield Point of the polymer mud reaches 10 Pa at these depths, which is sufficient to stabilize the Dibella well.
- The Apparent Viscosity (AV) or dynamic viscosity of the mud is a physical quantity that characterizes the resistance to laminar flow of an incompressible fluid [18,19]. It is strongly dependent on temperature [20]. The AV must be low to avoid erosion of the cake by the mud at the hole walls [21]. It must also be low compared to the plastic viscosity. For the polymer mud used in the Dibella well, this viscosity is 3 to 5 mPa.S. These values characterize a low flow resistance of the mud.
- Gel Strenght $G_{10''}/G_{10'}$: This property allows the polymer mud to consolidate the walls of the well by forming a cake on the walls thanks to the phenomenon of freezing [22]. In addition, when the circulation stops, the sedimentation speed of the cuttings is of the order of a few m/min, but the freezing of the mud increases rapidly [22]. However, a not very high freezing point is appropriate to avoid early sedimentation. Nevertheless, a low gel is not effective for the lifting of cuttings. For the polymer mud used in the Dibella well, the gel measured at 10 minutes (2 to 10 Pa) is about 2 to 3 times that measured at 10 seconds (1 to 4 Pa). These average gels are adapted to the geological formations of the Agadem oil field.
- The Hydrogen Potential (pH) is always greater than or equal to 7, as for the PHB mud, given the basic nature of the geological formations of the Agadem oil field. Such a pH will avoid any acid-base reaction that could lead to the formation of a new product that could cause the mud to malfunction [20,23].

6. CONCLUSION

The characterization of the muds used during the drilling of the Dibella well on the Agadem oil field, was carried out through tests carried out in the site laboratory as the drilling progressed. These tests made it possible to determine the types of muds adapted to the Agadem oil field as well as their physicochemical and rheological properties at each stage of the drilling execution. Thus, two (2) types of mud (Pre-hydrated bentonite and polymer) were used during the drilling of the Dibella well. The PHB mud, used from 0 to 800m depth, is characterized by a variable density depending on the lithology, a MARSH viscosity of 60 to 75 seconds and a pH between 8 and 9. The polymer mud, used between 800 and 2680 m, is characterized by an equally variable density, a MARSH viscosity of 55 to 60 seconds, a plastic viscosity of 10 to 20 mPa.S, a fluid pressure between 2 and 10 Pa, an apparent viscosity of 3 to 5 mPa.S, a Gel strenght $G_{10''}/G_{10'}$ of 1 to 4/2 at 10 Pa and a pH, always between 8 and 9. These parameters, which allowed the Dibella drilling to be carried out safely, can be used as a model for other wells in the study area.

7. ACKNOWLEDGMENTS

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