A Review on Montmorillonite (MMT) clay-based nanocomposites: MMT modification, Synthesis of nanocomposites and their applications

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Abstract

By planning earth-entrenched nanocomposites, huge headway has been accomplished in sphere of nanocomposites. Principle categories of earth minerals are supposed to be Montmorillonite (MMT), perlite, Portland cement (borate), atttaclay etc. The purity of clay minerals can affect the final nanocomposites properties. Thus, kind of mud, decision of mud modification as well as their conditioning plus manufactured strategies can impact the idea of last nanocomposite. Extensively utilized two proportion one sort mud minerals displaying promising advantages is Montmorillonite. Therefore, this review paper expects to depict utilizations of montmorillonite mud hinged nanocomposites in numerous domains like food packaging, wastewater treatment etc. and also their synthetic and modification methods including organic modifications (cationic, anionic, non-ionic, zwitterionic modifications), inorganic modifications and organic-inorganic modifications. Moreover, classification of clay minerals into different groups and type of clay polymer interactions are also discussed in this paper and for further in-depth studies, relevant references are also provided.

Keywords: Clay nanocomposites; Montmorillonite (MMT); intercalation; exfoliation; modifications.

Abbreviations: - MMT (Montmorillonite), MMTCs (Montmorillonite based nanocomposites), Na-MMT (sodium-Montmorillonite), CPN (clay based polymer nanocomposite), AMPS (2-acrylamido-2-methylpropanesulfonic acid), NIPAM (n-isopropylacrylamide), HDTMA-Br (hexadecethyltrimethylammonium bromide), TX100 (t-octylphenoxypolyethoxyethanol or TritonX-100), ZSMM (zwitterionic surfactant modified Montmorillonite), MMT@LDH(layered double hydroxide-Montmorillonite-nanocomposites), SB(sulfobetaine), PPCN (polypropylene nanocomposites), PEO (poly(ethylene)oxide), PVA (polyvinyl alcohol), OMMT (organophilic Montmorillonite), COS (chitosan oligosaccharide), GO-OM (graphene oxide-supported organic MMT composite).

1. Introduction

Earth hinge deposits (minerals), as a consequence of their immense facet area ,surface electric charge, idiosyncratic layered structure, porosity, different types of active sites and availability at low cost, can be considered as favorable or encouraging nanoparticles reinforcements to manufacture high performance and low cost nanocomposites. Mud or clay is inanimate flecks familiar as lamellar silicates also as phyllosilicates, furthermore generally utilized to plan CPN[1-3]. Low amount of inorganic nanoparticles(like clay minerals) can upgrade the exhibition of polymers for the time being appended to polymers where upon they are scattered, even small amount of clay minerals (commonly less than 5%) disseminated in polymer can also enhance the properties related to polymers[4-5].

There are three types of clay polymer interaction[5-6] *Micro composite*, where the clay fillers exist as aggregates in polymer matrix; *Intercalated* where chains are found between clay platelets and result in increased gap between clay platelets and *Exfoliated* which is expounded equally putrefaction of giant accumulates in direction of small flecks.

1.1 TYPE OF CLAY-POLYMER INTERACTIONS:-

1.	Micro composite	Consist of one single straight filament coated with layer of interphase and embedded in matrix and involves dispersion of mud deposit flecks inside polymer grid which are of thin plus infinitesimal measurements.
2.	Intercalated	Produce a nanocomposites incorporate fetters of polymers plus consecutive inanimate films, frequently results in increased interlayer spacing.
3.	Exfoliated	Result of extensive penetration of polymer.

1.2 Dirt deposits (Clay minerals) utilizing in polymer nanocomposites can be ordered in direction of three gatherings[7]:-

2:1 TYPE	Has a place with phyllosilicates deposit breeds. Precious stone assemble (aggregating aluminium polyhedron having 8 faces film {chunky} in the middle of dyad silicon tetrahedron films)	**Examples:** sepiolite, MMT, laponite, hectorite, fluorohectorite
1:1 Type	One silica tetrahedral layer is joined with one aluminium octahedral layer Each layer bears no charge. Through H_2 holding, facets are kept intact (in middle of –OH bunches in octahedral films plus O_2 in tetrahedral film of nearby facet)	**Examples:** Kaolinite, Halloysite.

Stacked H_4O_4Si	Clay comprises of predominant Si-tetrahedron films having film opacity. Essential film organization made out of interim wet antacid metal cations plus stacked silicate alignment (like aluminum tetrahedron).	**Examples:** Kane mite, octasilicate, kenyaite.

In nanocomposites mostly used mud deposits has a place with phyllosilicates deposit breeds that are liquefied Al_2SiO_5 accommodating Ca plus Na together with Mg or Fe. This bunch belongs to phyllosilicates mineral species like Montmorillonite, sepiolite, hectorite, beidellite and among these smectite clays, MMT is often used one as it is abundant and low cost clay while others are also useful depending upon selected applications. So, considering the importance of MMMTC, this review paper encapsulates the synthesis of emblematic composite materials with Montmorillonite and their workable applications.

2. Critique

2.1 Montmorillonite (MMT):-

Montmorillonite (MMT) is wealthy in inherent substance plus benign as well as two proportion one sort dirt deposits (clay minerals)[8]. It is very soft phyllosilicates group of minerals having magnificent surface assimilation adequacy, giant adequacy of cation swaping, colossal area of facet as well micro escalate layout.

Different names are used for MMT in several dialects (like in Catalan, Latin plus Spanish) it is called as *montmorillonita*, (in Germany, Hungarian and Slovak) it is called as *montmorillonit*; (in Dutch) it is called as *montmorilloniet* [9-10].

Himalayas, Caucasians, Ural, Andes as well as Wasatch in China, Georgia, Pakistan, Peru Ecuador, USA respectively are the five places where the major montmorillonite deposits were found[10-11].

Another clay mineral called Bentonite which mainly contained MMT and MMT further may contain sodium or calcium. Main fraction in Bentonite is Na-MMT which may be initiated conjointly with approximately twenty percent of several deposits in conjunction with gypsum, silica, $KAlSi_3O_8$ and $CaCO_3$[11].

MMT clay has erratic bodily plus synthetic belongings embracing upgraded surface reactivity, worked on tribological execution, extremely mixable in H_2O because of which it proclaims ideal associations with polymers, metals, panacea as well as M_2O_3[12].Thus , on account of these unique properties belongs to MMT clay, distinguishable newfangled MMMTCs can be formulated that have prominent applications.

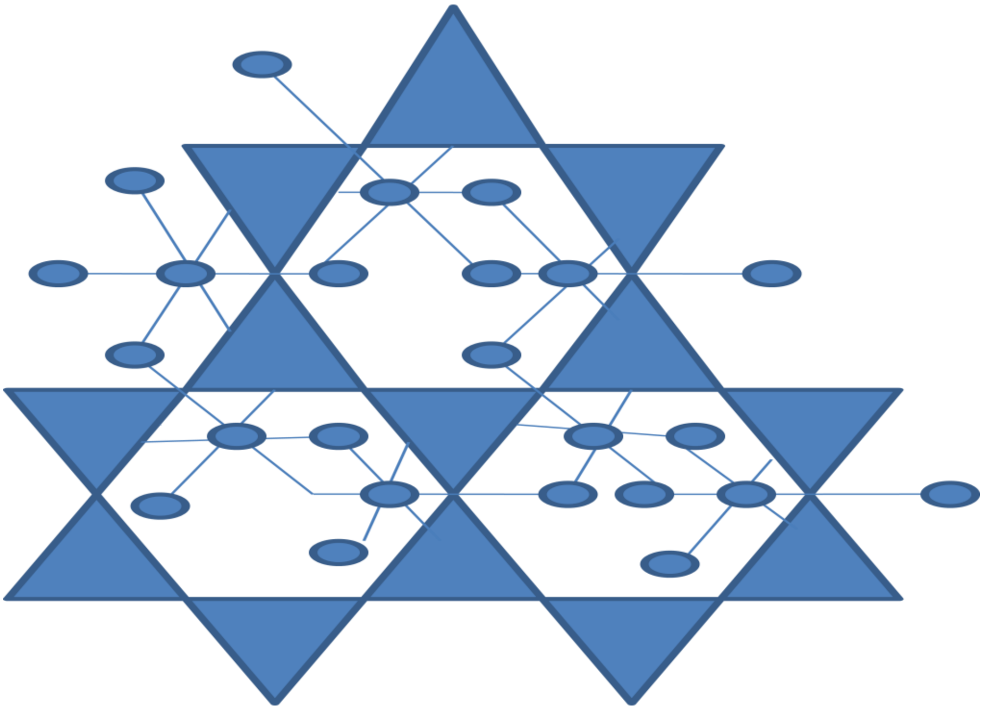
2.1.1 Erection of Montmorillonite:-

Bodily formation of MMT exists perceptibly in linens as well as coatings.

- One and all coatings are made out of two sorts of underlying linens :-OCTAHEDRAL plus TETRAHEDRAL which are explained using table inspired by[10]:-

Structural sheets	Composed of	Linked to	Resulting in
Tetrahedral	Silicon oxygen tetrahedral sheets (O—Si—O)	Neighboring tetrahedron through partaking ternary edges.	Sextet web.
Octahedral	Aluminium or magnesium in six fold (O—Al(Mg)—O)	O_2 across tetrahedral linens.	Evolution of layer through assembling bifurcations.

Staying fourth edge of every tetrahedron shapes a piece of nearby octahedral sheet[10, 13].



Sextet construction of –OH plus oxygen ligands related to octahedral coating. Picture inspired by[13].

2.1.2:- Important natural physical properties of MMT[10, 14-16]:-

- *Colour*: - White, Pale pink, Blue, Yellow, Red-Green (presence of valence Mn produces pink to red coloration).
- *Optical properties*:- Biaxial
- *Fracture*: - Irregular, Uneven.
- *Sheen*: - Earthy, Tedious
- *Transparency*: - Pellucid
- *Cleavage*: - Perfect
- *Crystal system*: - Monoclinic.
- *Density*: - 2-3gm/cm^3
- *Blueprint*: - $(Na, Ca)_{0.33}$ $(Al, Mg)_2$ $(Si_4O_{10})(OH)_2.nH_2O$

Montmorillonite shaped in spheres of squat precipitation, unfortunate waste plus filtering, high pH and electrolyte fixation. It gets framed through enduring of volcanic debris beneath unfortunate seepage circumstances, briny climate or from basic and intermediate igneous rock[20, 87].

2.1.3:- Functional properties of Montmorillonite:-

(i) Particular facet sphere (SSA):-This characteristic defines the facet sphere of material particles divided by mass of material particles. This SSA value can be used to find out the types and properties of material. In numerous soils plus alleviations, earth deposits give biggest part of all out deposit facet sphere. Thus, Cation exchange, adsorption of natural matter and also adsorption of many nutrients and pollutants are majorly controlled by clay minerals[17].

Level of delicacy, molecule charge, measure of contamination as well as capacity of coagulation is the common factors which can control the SSA values[18]. Explicit facet sphere assays (SSA values) are in uninterrupted contact in company of CEC esteem[19].

(ii) Swapping ability of cations (CEC): - CEC is how much interchangeable cation. If the CEC is higher, negative charge will also be higher and more cations can be held[10]. Clay minerals have the incredible ability of drawing plus holding in cations due to its substance organization. Among mud minerals, MMT has most noteworthy CEC as CEC changes as indicated by kind of mud. In MMT, CEC values rely most extensively on measures of isomorphic replacements in octahedral locales. Mostly with increase in SSA values, CEC also increases but due to the acid treatment, it can be clearly seen that there is decrease in CEC values with increase in SSA values[18].

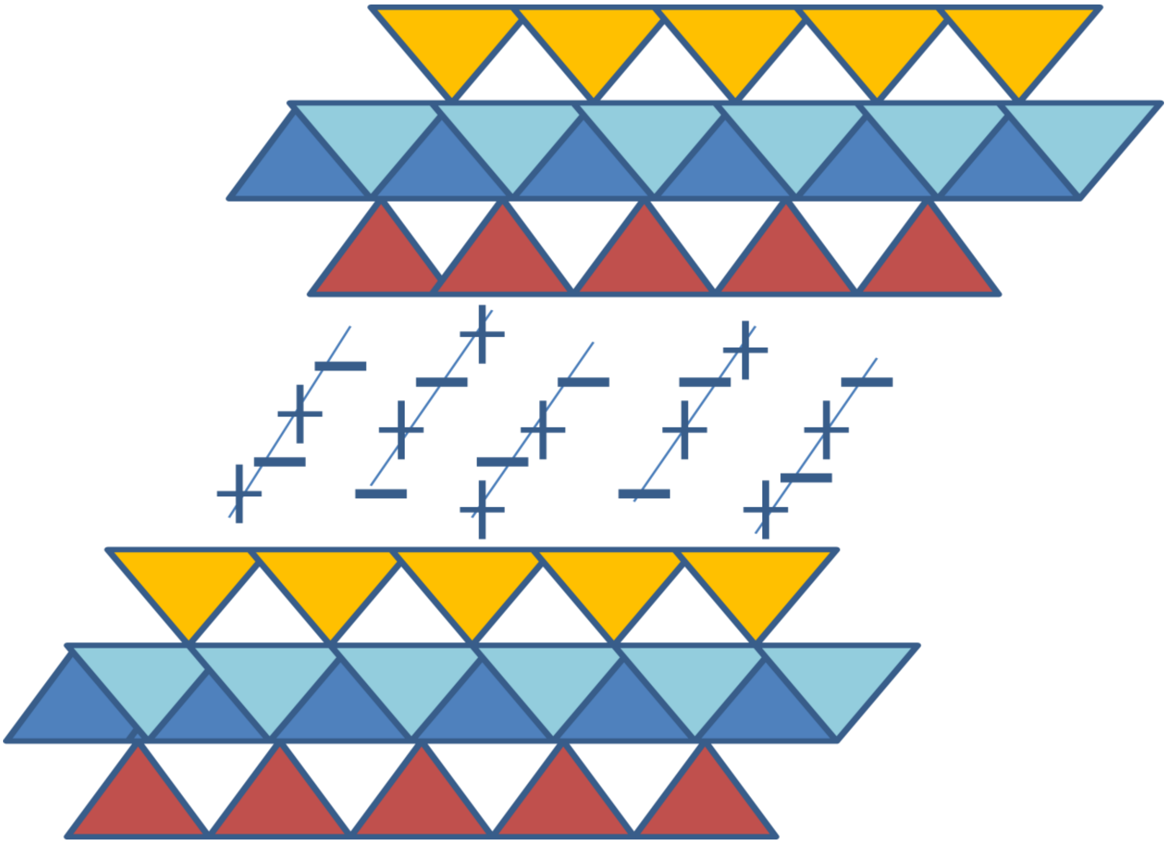
Other functional properties of MMT are its (iii) *electrical conductivity* and (IV) *heat resistance*[10] as montmorillonite may be stable at 300˚C under appropriate chemical conditions. Last annihilation of montmorillonite cross section starts nearly 600°C, backing deficiency of (--OH) grid H_2O plus finalized roughly at about 800 to 850°C[21].

Clay minerals also tend to have (v) *water sorption properties*[10]. MMT will absorb more water than other common clay minerals (like Kaolinite, illite and chlorite) like Na-MMT take up about 250% more water than hectorite did in 10,000 minutes and hectorite in 1000 minutes took about twice as much water as did the Arizona which in turn proceed to take up more water than tatatila[22].

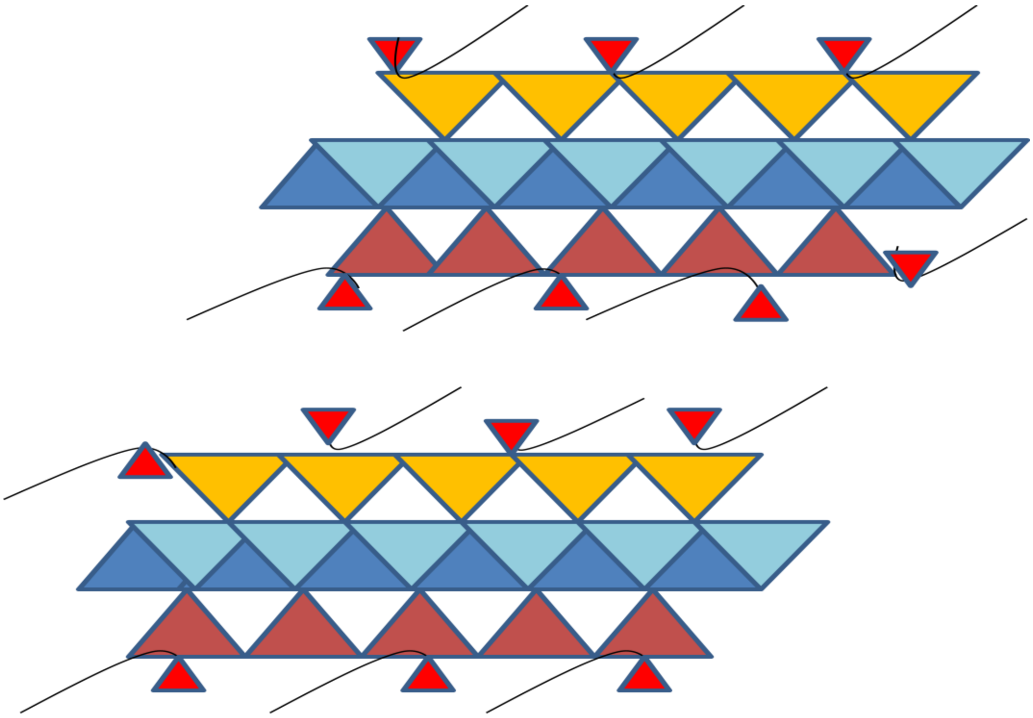
3. MMT's Modification:-

Sometimes montmorillonite has poor compatibility with polymers due to its hydrophilic and oleo phobic properties. In such cases, there is need of modified MMT and to obtain the composites with enhanced properties. A few courses have been utilized to change MMT incorporating: interchanging particle (ions) with natural particles, uniting of organics plus facet assimilation[28].

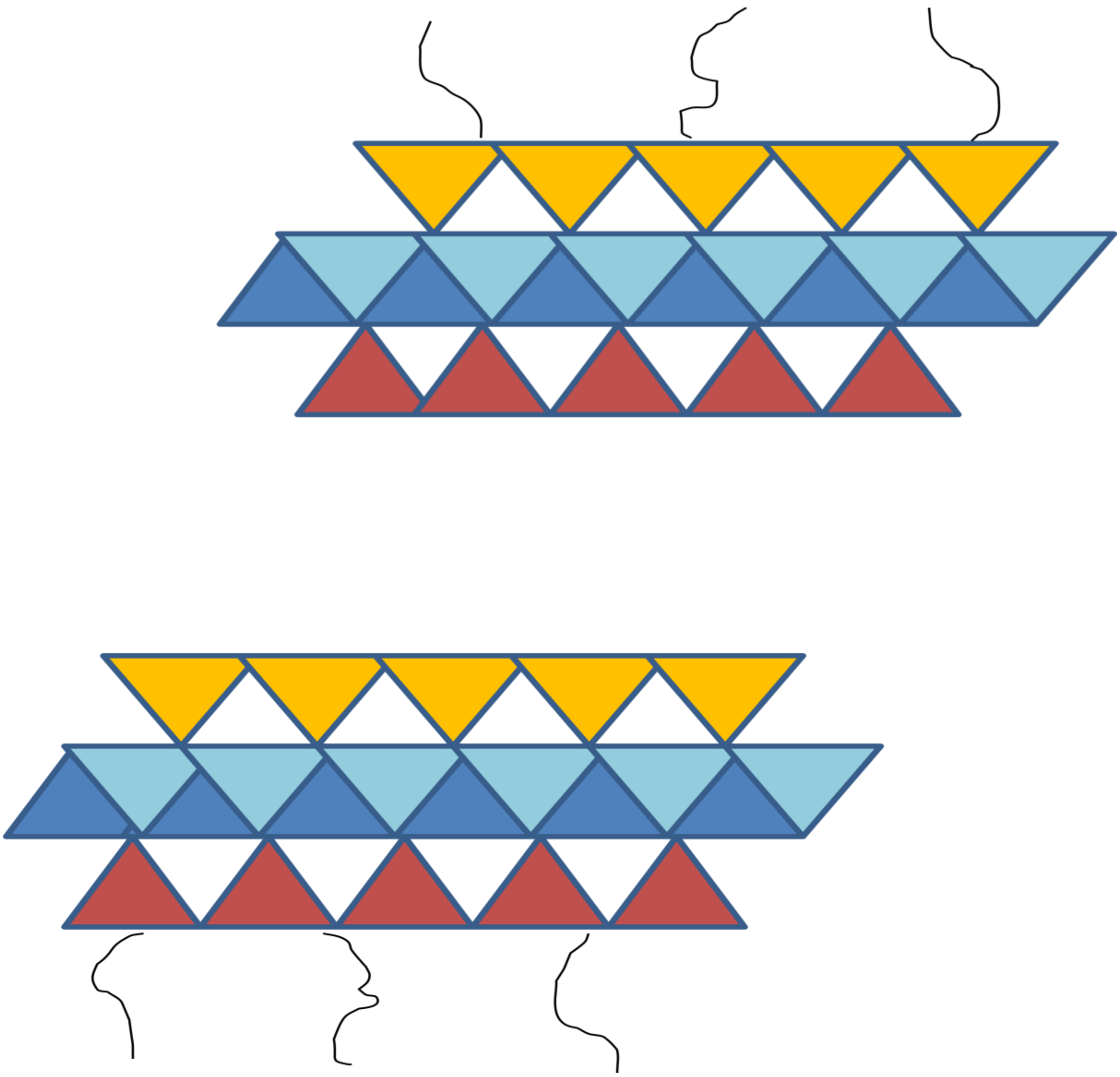
Organo-montmorillonite: Pictures inspired by[28]:-



(A). Cation exchange



(B). Surface adsorption



(C) Grafting

3.1 Mainly there are three methods of modifications:-

Hydrophobic interaction	Changes over aqua-loving facet of coating in direction of aqua-affrighted (in this manner working on one similarity of micro-mud into polymer grid)
Intercalation	Physical process through which capacious speck for example color as a choice polymer is embedded in display *(width of gallery gets not much affected.)*
Exfoliation	Intelligible disturbance of sheets that in turn temporally isolated prompting nanoscale scattering in polymer lattice (*gallery gets extended from typical size of 1nm)*

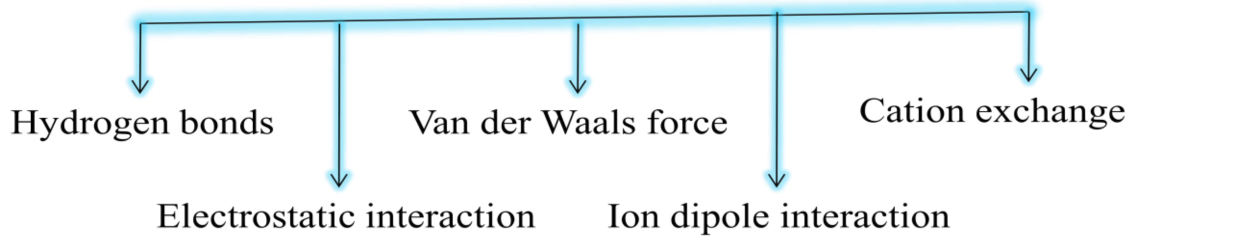
3.2 Various techniques of modifying the montmorillonite are known. They are as follows:-

3.2.1 Organic modification:-

Naturally changed Si_2O_5 got from normally happening mud deposits are supposed to get nod as organoclay. Through trading first intergalactic space in middle of cations for organo cations organo-loving facet might be produced[89]. Organic modification can improve level of scattering related to MMT in direction of polymer grid showing ameliorate as well as escalate mechanical and physical features directed towards diversified levels. Along these lines, MMT conglomerations show wide applications in countless spheres[23-24].

To prepare organically modified MMT, a few specialists have utilized intercalation techniques which may result in great degree of scattering plus enhanced warm-machine-based features[25].

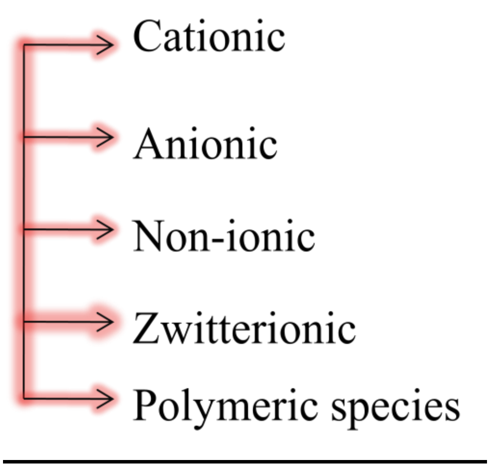
MULTIPLE INTERACTIONS INVOLVED IN ORGANO MODIFICATIONS[28] LIKE:-



Studies which are showing the feasibility and beneficiality of organic modification of MMT are shown below[24]:-

Reference	Study
Greesh el al.[26]	Revealed that principal collaboration among AMPS plus mud (clay) was dominant impetus for assimilating AMPS on facet belongs to MMT while modifying Na-MMT with AMPS and NIPAM.
Kumar and Kannan[27]	Understanding governable activity of shedding plus insinuate of MMT, found that amount of molecular weight of Montmorillonite epitaxial arena might be regulated through governing free radical polymerization cadence.

COMMONLY USED ORGANIC MODIFIERS MAY BE LISTED AS:



(a) Modification with cationic surfactants: Cationic surfactants are positively charged functional groups, composed of polar (quaternary ammonium units) and non-polar (different alkyl) parts like cetrimonium chloride, stearamidopropyl dimethylamine.

Modifications with cationic surfactant are done through interchanging normally-happening cations at mineral ion swap locations for natural cations of cationic surfactant. The plan of natural cations in epitaxial of natural-mud profoundly relies upon sheet charge of mud minerals or deposits as well as size of fetters of natural particles[29]. Cationic wetting agents hinged sorbs family is comprehensively utilized in direction of climatic restoration[30-31]. According to literature, consistently utilized cationic surfactant in direction of alteration of mud deposits is $C_{19}H_{42}BrN$[32].

(b) Modification with anionic surfactant: Anionic surfactants carry negative charge on its hydrophilic end and negatively charged anions get created when these surfactants are mixed with water. Aliphatic $C_nH_{2n+1}COOH$ are transcendently utilized anionic surface active agents[33] (got from normally happening plant fats plus creatures); Sulfonic acid is another significant category related to anionic wetting agent. Fluorinated anionic surface-active agent may also be used but due to their high half life time, they are usually environmentally critical[33].

Normally utilized anionic wetting agents in light of $C_nH_{2n+1}COOH$ and Sulfonic acids are given below. Table inspired by[33]:-

Based on	**Examples**
Carboxylic acids	Sodium stearate, Sodium lauroyl sarcosinate, Cholic acid, Deoxycholic acid, Zonyl fluorosurfactant, Glycolic acid ethoxylate laurylphenyl, $C_{55}H_{122}O_8$.
Sulfonic acids	Dioctyl sodium sulfosuccinate, ammonium dodecyl sulfate, 3-sulfopropyl ethoxylate laurylphenyl ether, sodium lauryl ether sulfate, $CH_3(CH_2)_{11}OSO_3Na$.

(c) Non- ionic surfactant modifications: Non-ionic surfactants are neutral in nature and their hydrophilic end does not have any charge on it. The key difference between ionic and non-ionic surfactant is in their formulation. Non-ionic surfactants are sensitive to temperature changes and have relatively low water solubility. Non-ionic surface active-agent hinged naturally-modified clay has extra chemical firmness plus non-toxicity, also through H-holding among oxides plus $[SiO_{4-x}{}^{(4-2x)-}]_n$, more prominent epitaxial layer separating can be accomplished[32, 34-36]. One of the most popular non-ionic facet active agents is $C_{14}H_{22}O(C_2H_4O)_{n\ (n=9-10)}$ or TX-100[37-38] but there is need of extensive study on the interaction of MMT clay with TX-100.

(d) Zwitterionic surfactant modifications: Zwitterionic surfactants may bear couple of –ve as well as +ve charge which may have dependent pH values either is permanent. They are also called as amphoteric surfactants. It is a gel enhancing system for example erucyl amidopropyl betaine. They acquire elevated decomposability, resolvability as well as biological safety[39]. Using MMT plus ternary zwitterionic wetting agent having several C_nH_{2n+1} chain at divergent aggregations (usually between 0.2-4.0 CEC), a series of ZSMMS were synthesized[40].

Inanimate positive charge particles in epitaxial coating arena of MMT get interchanged with positively charged groups of zwitterionic surfactants and hence these surfactants get entered into interlayer of MMT so-as-to facet features related to given stuff might modified in direction of aqua-phobic either oil-loving . Also existence of pair of Cation plus anion in zwitterionic surfactants imparts special properties (like extraordinary electrify-cardiogram characteristics of epitaxial stage) to ZSMMs[40-43].

3.2.2 Inorganic modifications:-

For improving assimilation capacity of regular MMT for weighty metal particles, inorganic methods are used to modify MMT like[24]:-

- Tart incentive alteration.
- Inanimate saline moderation.
- Buttress conversion.

Inorganic modification is widely used for[24, 44]:-

- Increasing epitaxial span.
- Strengthen thermal stability of MMT.
- For eliminating weighty metal particles it may utilized as assimilation substance.
- Getting ready montmorillonite hinged bi-spatial conglomerations.
- Improving performance of Montmorillonite.

Examples of some studies involved inorganic modifications are shown in the table below:-

Reference	Study	Result
Cheng et al.[47]	Using acid modification prepare montmorillonite micro-mud/$C_4H_2O_3$ amended PPCNs	Nanoclay changed the thermodynamic properties of $(C_3H_6)_n$.
Chen et al.[46]	Modify MMT by sodium group.	Results in adsorption of heavy metals like Pb^{2+}, Cd^{2+}, Cu^{2+}, Co^{2+} etc.

Along with these, *Organic-inorganic modifications* are also used, as getting ready inanimate (inorganic)-natural conglomeration amended Montmorillonite proffers in further developing its assimilation potentiality for toxins[45].

3.2.3 *Surfactant modifications* and *Pillared modifications* are also helpful in[24] improving assimilation acuteness relating to Montmorillonite for weighty metal particles and increment capacity of small openings, facet region, more grounded resistance to pH, co-existing inorganic particles respectively.

4 Synthesis of MMMTCs:-

There are several methods of synthesis to make clay based nanocomposites. Every method comprises of a few moves toward accomplish polymer nanocomposites plus starts in company of organoclay and at times unblemished clay[48]. Some of these methods may include:-

4.1 Intercalation Method:-

This method is actual cycle with aid of which macromolecule is embedded in display. Such particle gets circumscribed through dyad earth sheets plus gets deactivated also gets safeguarded. Insinuate (intercalation) may grow epitaxial dividing, modify construction of host particles as well as more fragile Van der Waals power[90].

4.1.1 KEY CHALLENGES IN PREPARATION BY THIS METHOD[24]:-

→ How to foster successful strategy for strip off overlaid composite edifices?

→ Step by step instructions to change plus manage gathering of micro sheets for acquiring nano-composites having explicit designs.

4.1.2 Certain examples of MMT based nanocomposite prepared by intercalation method:-

1. Preparation of MMT@LDH[24]:-_Utilizing Montmoriloonite's lofty explicit region, lamellar organization, great warMMTh strength, anionic mud deposit LDH and cationic earth deposit MMT have been combined to improve structural features of LDH and because of charges between layers of MMT and LDH are completely opposite and they are similar in structure, Hence regular circumstances for mix of LDH plus montmorillonite get created using electrostatic collaboration.
2. MMT-PEO nanocomposites are also prepared using intercalation of PEO within the inter galleries of MMT[49].
3. Polyaniline-montmorillonite nanocomposites can also be prepared by mechano-chemical intercalation Method[50]. Hence many more nanocomposites can be synthesized using intercalation method as it can be called as *Environmental benign approach*.

4.2 In-situ polymerization[91]:-

In-situ polymerization[91] involves processes which consist of an initiation step, from this moment forth; a series of polymerization steps will be there, resulting in formation of polymer nanocomposite from nano-materials[51].

4.2.1 In-situ polymerization includes benefits like[51]:-

- Incorporate utilization of savvy stuff.
- Simple to mechanize.
- Having capacity of incorporating within any extra utilizing plus warming techniques.

In-situ polymerization is called as standard technique of preparing clay nanocomposites act in accordance by commencement through practical gathering in natural cation, afterwards polymerization comprising of intercalation related to monomer in company of clay facet[52].

4.2.2 Various examples of MMMTCs preparation using In-situ polymerization methods are known like:-

1. Planning of $(C_2H_4)_n$ micro-conglomerations involving blending of micro-particles in perfect monomer trailed through polymerization within sight of scattered micro-particles utilizing couple of normal plus natural changed MMT as supporter and various rates of dirt[53, 92].
2. Planning related to $(C_8H_8)_n$/Montmorillonite nanocomposites through enlarged coated $[SiO_{4-x}{}^{(4-2x)-}]_n$ inside fluid monomer arrangement[54], this prepared nanocomposite has better thermal stability than unadulterated polystyrene stalks and communication among dirt plus fetters of $(C_8H_8)_n$ monitor versatility of fetters[93]. This multitude of enhancements rely upon different boundaries, for example, dirt appropriation, aspects, form elements, peeling, polymer earth collaboration[94], structural nature of clay; its swelling and ion exchange properties etc.[54-56].

4.3 Exfoliation method:-

For creation of MMT/polymer nanocomposites, fundamental courses of peeling of montmorillonite are[7, 57]:-

4.3.1 In-situ exfoliation: - For in-situ shedding, MMT is scattered in monomer arrangement and the monomer enters its epitaxial-coating arena, trailed through in-situ polymerization. At the point when the monomer is emulsifiable also requires an in-situ polymerization cycle really at that time in-situ peeling of MMT is doable[57].

4.3.2 Solution exfoliation:- In solution exfoliation[7], using diluents in which polymer is dissolvable, coated mud is shed in direction of solitary thrombocytes, at that point mud adjournment[95] also polymer are mixed together plus assimilated above platelets. By vanishing, diluents are at long last wiped out from clay-polymer multiplex. Hence, to bring off mixture peeling MMT, added substances, natural transformers, dissolvable plus polymer are in direction of solitary reactor[57].

4.3.3 Melt exfoliation: - In this Method[57], under the shearing force; trailed through warming solution, MMT is blended in company of thermoplastic polymer ($C_{27}H_{36}N_2O_{10}$). Melt exfoliation is elementary and much engaging method as compared to solution exfoliation and in-situ exfoliation.

4.4 Tape casting method:-

Tape casting method is a fabrication technique to form plastic thermoformed sheets (by which solitary coat either many faceted $(C_2H_4)_n$ extruded linens of $(C_8H_8)n$, $(C_3H_6)_n$ plus arduous $(C_8H_8)n$ can be processed)[24]. This process can also produce ceramic sheets from ceramic slurry.

For example, Xu et al.[58] prepared poly-lactic acid/sodium hinged montmorillonite/dual coated hydroxide triplet amalgam membrane. Using tape casting technique, there exist covering of pre-arranged sequence of sheet crusting solution beside polytetrafuoroethylene lamina through an automatic film coater.

4.5 Solution blending method:-

Initially, Polymer is permitted to disintegrate in reasonable dissolvable in mixture mingling/mixing technique[96]. Thus, given technique shows particularity for water-soluble bio-polymer[59]. Dirt particle can likewise scattered in similar dissolvable independently. Diluents' mixture and clay/solvent dispersion are mixed and permitted to get united for progressive time frame trailed through projecting against level abettor plus evacuation of diluents through dissipation[60-63, 96].

For example, Nylon-6/MMMTC having improved machine-based belongings can be made through mixture aggravating[65].

4.6 Melt-blending method:-

In this method, mud materials are straightforwardly buttressed in polymer[96]. Thus, mixing of polymer and clay material is better in melt blending as compared to solution blending method[63]. Polymer-clay mixture at room temperature surpassing liquefying extremity of polymer[64, 96] is allowed for annealing process. After getting polymer-clay nanocomposite secondary processing is also get involved in it.

Secondary processing

- Compression molding
- Injection molding
- Extrusion
- Blown film molding

For example, preparation of PEO/Na-MMT clay based nanocomposites via dissolve blending[66] above thin spike co rotating dissolve blender. To explore the joined impact of $(–CH_2CH_2O--)_n$/clay phase plus $(–CH_2CH_2O--)_n$ dissolution profile of aprepitant[66] (APR), APR occurred to be stacked in giant sub-atomic poundage $(–CH_2CH_2O--)_n$ and mud based $(–CH_2CH_2O--)_n$ nanocomposite through dissolve blending cycle.

4.7 Electro spinning method:-

To produce polymer nanocomposite having magnificent properties, electro spinning method is used which is successful innovation, minimal expense as well as extremely straightforward. Electro spinning method has idiosyncratic of not only electro spraying but also traditional arrangement clay turning of filaments. Electro spinning process uses an electric force i.e. elevated potential get enforced directed towards polymeric liquid[97] to induce a charge thread enclosed by liquid. At a moment that complimentary amount of charges are achieved, liquid will emit coming out of the bead at extremity of pointer and form Taylor cone and then arrangement expel coming out of spout framing a stream[98] travelling towards locate related to minor voltage[99].

4.7.1 The parameters affecting electro spinning are[67]:-

- Arrangement boundaries of polymer.
- WarMMTh conditions.
- Handling circumstances that incorporate enforced potential.
- Impact of gatherer.

Electro spinning method might contemplated at time that expansion of mixture strategy , while it depends upon comparative beginning combination[59] and this method normally produces nano-structural filaments via electro-hydrodynamic process[59].

Several electro spun nanocomposites micro-filaments in direction of liquefied mixtures in company of $(C_{12}H_{24}N_2O_9)_n$, $(C_2H_4O)_x$ plus pullulan same as polymer matrices as well as MMT, Ag-nano-particles as inorganic materials have been fabricated using electro spinning method[67].

5 Applications of MMMTCs

Day by day, there is an increase in the field of applications of nanotechnology. MMT also displays auspicious applications including:-

5.1 Food packaging[59, 68]:- We pick out nano-particles get going willingly in direction of nourishment as well as creating better nourishment sources in company of[68] befitting healthful attributes[68], With regards to MMT's functions in food[68] packaging. For enhanced machine-based plus obstruction features in development related to food bundling, nanoclay is an ideal nanostructure to put up such properties as its hydrophilic nature permits it to be consistent with hydrophilic polymer/bio-polymer, also by use of OMMT; it can be mixed with hydrophobic polymer/bio-polymer.

5.2 Wastewater treatment (Expulsion of weighty metals from H_2O[69])[12, 69]:-

Lately developed MMT nanocomposites can be used in ending of poisonous genus like M^+, M^- (metal ions).

Over evacuation of different metal particles utilizing crude as well as adjusted[69] MMT, many studies are accounted for in writing as displayed below:-

Studied using	**Adsorption of**	**Maximum adsorption capacity**	**References**
Raw MMT	Pb (II)	28mgg^{-1} after modification of clay [131.579 mg g^{-1}]	70-73
Raw MMT	Cu (II)	18.69mgg^{-1} (due to proper reaction conditions)	74-75
Modified MMT	Cu (II)	48.3mgg^{-1}	76
Raw MMT	Cd (II)	12.63mgg^{-1}	70, 72, 77
Modified MMT	Cd (II)	15.25mgg^{-1} (increased due to change in surface charge chemistry)	77

Removal of other heavy metal ions like Cr(III), Nickel ions , Mn(II), Zn(II), Hg(II), Ba(II), Co(II)[100], As, Sr, Ca as well as other heavy metals like iron using raw or modified MMT are also reported[69].

5.3 Pollutant adsorption: - Adsorption is compound plus bodily course of eliminating toxins coming out of intermediate of gas stage through abolition of poison in direction of intermediate related to diluents (liquid phase or dry bulk solid). This adsorption method has the properties of giant productivity, ecological insurance, lofty evacuation proficiency plus minimal expense[78].

Wei et al.[79] prepared GO-OM composite which shows features of great collaborative assimilation for blended toxins within liquefied mixture. Graphene oxide-carried organic MMT is also one promising sewage treatment material.

MMT@LDH[24] also enhances the adsorption effect. In comparison to MMT@LDH alone Mg-Zn Al (LDH)@MMT[80] would be advised to assimilation effect as well as improved with increase of temperature[80].

5.4 Corrosion Resistance: - Specialists within sphere related to corrosion resistant have contemplated coating in company of supercilious corrosion-inhibiting properties for a long time. Due to CEC and interlayer anion exchange capacity of MMT and LDH respectively, bipolar coatings are formed whose main characteristic is that its groundwork shows layer features of interchanging negative charge[24, 81]. Thus, corrosion resistance properties of MMT@LDH show best performance among all coatings because of acuteness of positive plus negative charge by surface layer plus primer respectively.

In this way, we may get new ideas for further developing the anticorrosion materials.

5.5 Sustained drug release:- MMMTCs have good biocompatibility, as MMT is exceptionally protected in course of implementation interval as well as having no harmful responses due to the reason that after oral administration MMT is not absorbed plus could not get injected in blood dissemination[24]. For example MMT and LDH can be the flawless option for sustained drug release carriers because these mud deposits can oblige a lot of medications among the coatings[82].

Kevadiya and Bajaj[83] also use MMT in sense of medication conveyance transporter to accomplish predetermined extremity arrival of medications in body.

5.6 Flame retardant effect: - Flame retardants are chemicals used to decrease the ability of materials to ignite. Layered double hydroxide plus montmorillonite both respectively joined with different particles working on warm solidness[84, 24].

Ming at al.[85] combined montmorillonite plus $C_{140}H_{42}O_{20}$ in company of $(C_2H_4O)_x$ also procures amalgam materials exhibiting great fire resistant features.

Bian et al.[86] prepared $C_{140}H_{42}O_{20}$-improved timber ascetic-spa /Montmorillonite micro-amalgam sheet having lofty firmness and magnificent fire resistancy plus aqua-phobicity.

5.7 others: - Other applications of MMT clay includes Biomedical use namely medication conveyance, laceration betterment, orthopaedic plus bruise abscission, regenerative therapies[12]; Acid-base bifunctional catalysis (like MMT@LDH, MMT is utilized in tart infused reactions)[24]; photo degradation of pentachlorophenol (e.g. Bi_2O_3-TiO_2 MMT nanocomposite) because clay supported semiconductor nanocomposite improves photo catalytic movement giving large facet sphere, initial arena as well as CEC[87].

Conclusion

Present audit summing up synthesis, applications plus modification methods related to Montmorillonite. Hydrophobicity as well as poor compatibility of MMT with polymers restraint its extensive application but it also exhibits firm immersion as well as assimilation of H_2O also great CEC presentation. Thus, MMMTCs can be made applicable in various fields due to its wider applications. Several organic, inorganic, and organic-inorganic methods of modifications of MMT are studied under which only a few studies were done on ZSMM and its properties are still unclear. Therefore future work should be focused to expand the applications of organic MMT into biomedical field like drug carriers, catalysis etc. and also work should be carried out on supplementary mud deposits like sepiolite, Kaolinite along with anionic mud called LDH at same time it is clear that clay minerals are cost effective and flexible raw materials for polymer nanocomposites due to their unique structure, abundance in nature and rich intercalation chemistry.

Conflict of Interest Statement

No potential conflict of interest was reported by the authors.

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