ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Investigation into Adhesive Properties of Sodium Carboxymethyl Cellulose Aiming at Development of Dust Suppression Layer.

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ABSTRACT

Various approaches to dust suppression are currently applied in order to reduce negative air impact of waste technogenic sources [2]. One of the most popular methods of dust suppression is fabrication of protective layers, the main task of which is overcoating of dusting surfaces. Generally such layers have well-defined adhesive structure promoting adhesion with dusting surfaces. The article describes study into the properties of sodium carboxymethyl cellulose aiming at its application in order to fabricate dust suppression layer . The main physicochemical properties of the substance are given. A procedure is proposed to study adhesive ability of substance based on chip boards. Experiment is described which determines adhesive ability of gluing components of protective dust suppression layers. Reasonable range of sodium carboxymethyl cellulose concentration, 0.7-0.9 %, is determined in solutions aimed at fabrication of dust suppression layers. Major advantages and disadvantages of the considered substance are discussed.

Keywords: Sodium carboxymethyl cellulose, dust suppression, adhesion, dust, mechanical strength, reasonable concentration, solution.

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ISSN: 0975-8585

INTRODUCTION

Vast areas of disturbed lands are formed upon mining and processing of mineral resources, generating the sources of dust flows [1]. The major types of such degraded territories are waste dumps, tailings pond beaches, mud pits and so on [2].

An important factor of efficient reduction of dust generation on surfaces of external waste dumps is fabrication of bonded structure in the upper coating layer, which would provide its improved strength properties based on coagulation of dusting material and its bonding into granules, as well as agglomerating of the granules between each other and coarser particles with simultaneous increase in bioactivity of the bulk in order to perform rapid reclamation [3, 4].

Activities on fixing of dusting surfaces include procedures related with application of bioproductive ameliorants onto dusting surfaces, which provide their structuring and resistance against wind erosion [5]. In Russia turf, flour and sapropel are relatively widely applied as bioproductive ameliorants and soil conditioners. However, rather frequently adhesive properties of these substances are insufficient, especially in regions with strong winds. Additional bottlenecks involve costs of such soil conditioners, procedure of their application onto dusting surfaces and others. As an alternative variant we propose application of sodium carboxymethyl cellulose (Na-CMC).

EXPERIMENTAL

On the premises of National Mineral Resources University a set of experiments was carried out aiming at determination of adhesive and bioproductive properties of sodium carboxymethyl cellulose. The chemical formula of this salt is: $(C_6H_7O_2(OH)_{3-x}(OCH_2COONa)_x]_n$, where n = 300–1000. It is a amorphous colorless substance with the density of 1.59 g/cm^3. Its softening point is 170°C.

The main properties of sodium carboxymethyl cellulose are as follows:

- readily water soluble, promotes thickening of all aqueous solutions;
- viscosity remains stable for a long time;
- accumulates water;
- steady stabilizing and bonding properties;
- synergetic effect with biopolymers of protein nature (casein, soya protein);
- generates transparent and solid film;
- not solved in organic solvents, oils and fats; odorless and tasteless, physiologically safe, recognized as safe food additive [6].

On commercial scale Na-CMC is produced by interaction of alkaline cellulose with chloroacetic acid or its sodium salt in the presence of NaOH. Technical product contains 50-70 % of ester. In order to obtain purer Na-CMC the technical product is washed with aqueous solution of low alcohols.

Upon solving in water sodium carboxymethyl cellulose forms viscous transparent solutions characterized by pseudoplasticity, and even by thixotropy for certain product types (ability to arbitrary restore initial structure destroyed by mechanical action).

In aqueous solutions Na-CMC, exerting properties of surfactant, fits well with other water soluble organic substances, for instance, biological humus. The compound is destructured in aqueous solutions of mineral acids and alkalis in the presence of oxygen. Aqueous solutions of Na-CMC generate transparent films characterized with relative elongation of 8-15 %. Dry Na-CMC exerts weak corrosive impact; it is biologically inactive and resistant against biodestruction, however, its aqueous solutions upon long term storage in air are exposed to ferment hydrolysis.

Na-CMC is used as a thickener and stabilizer of clayish slurries, thickening agent in textile industry, as wallpaper paste [7].

The Chair of industrial safety, National Mineral Resources University within some months carried out experiments on application of Na-CMC as a binder. Such binder is characterized with environmental purity, high gluing ability, affordable prices and sufficient quality [8].

Binding properties of Na-CMC were estimated by mechanical properties of chip boards on its bases (in terms of bending resistance, MPa) [9, 10]. Another important experimental stage was analysis of Na-CMC as a binder for fine disperse materials (as exemplified by sand) (Fig. 1). The third stage included analysis of tensile strength and hygroscopicity of films simulating surface element of protective dust suppression layers based on low-substituted sodium carboxymethyl cellulose.

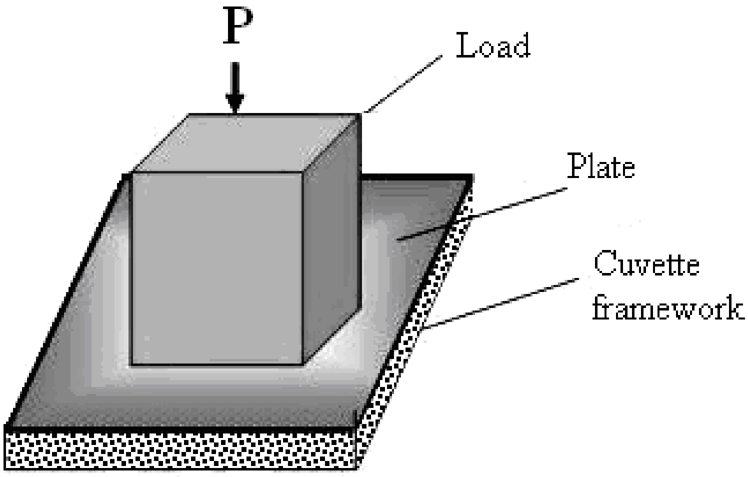

Fig. 1. Study of adhesion of Na-CMC with sand.

RESULTS AND DISCUSSION

The best results were obtained with application of 0.8 % Na-CMC (on dry basis) (Fig. 2). Sufficiently high activity of Na-CMC as a binder is achieved upon its swelling in 3 min and remains steady up to 10 h, the trend to decrease in its gluing properties can be observed (Fig. 3).

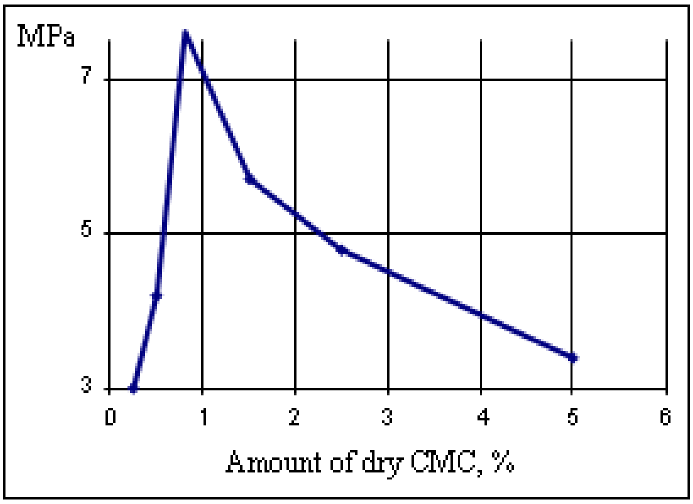

Fig. 2. Mechanical strength of chip board with Na-CMC.

In addition, a series of experiments was carried out with application of Na-CMC as a binder for fine disperse materials (as exemplified by sand) in the concentration range from 0 to 5 %.

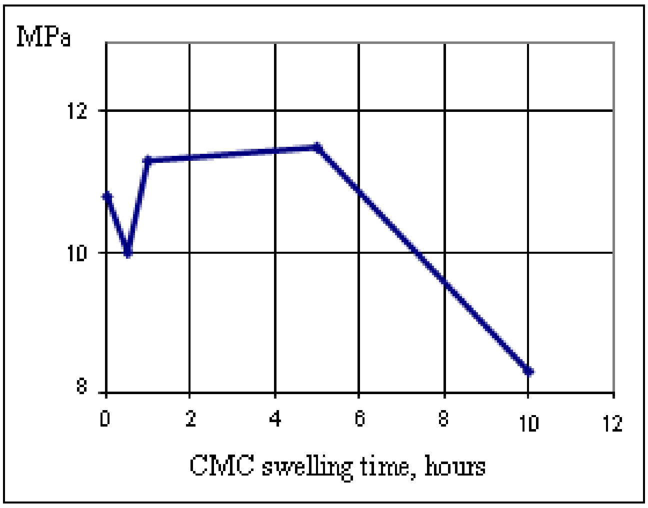

Fig. 3. Adhesive properties of Na-CMC.

The experimental results revealed that already at 0.8 % Na-CMC good binding properties are achieved. The values of strength at compression $\delta_{сж}$ and at tension δ_p were achieved as a result of testing.

Upon further increase in the binder content to 10 % the density of specimens increases. Drying of specimens leads to increase in their strength [11].

It is established that the optimum range of Na-CMC concentration in disperse material (sand) is $C_{Na-CMC} = 0.7 - 0.9\ \%$. Average value of this range $C_{Na-CMC} = 0.8\ \%$ is adopted, which is recommended for further use in order to fix dusting surfaces of technogenic arrays.

About 40 experiments were carried out in general. The results of processing of experimental data are illustrated in Fig. 4. In the experiments Na-CMC always behaved as a binder, however, it should be mentioned that with increase in Na-CMC content there is observed certain trend of increase in strength of bonded particles, but the cost expenditures for purchasing of additional amounts of the binder [12] evidence that the percentage of 0.7-0.9 % is the most reasonable.

Upon studies in adhesive properties of Na-CMC viscous solutions of low-substituted sodium carboxymethyl cellulose with sufficiently high polymerization rate were obtained. They were used as a basis for films intended for potential dust suppressing function, as well as for study in the major physical and technical properties of these films.

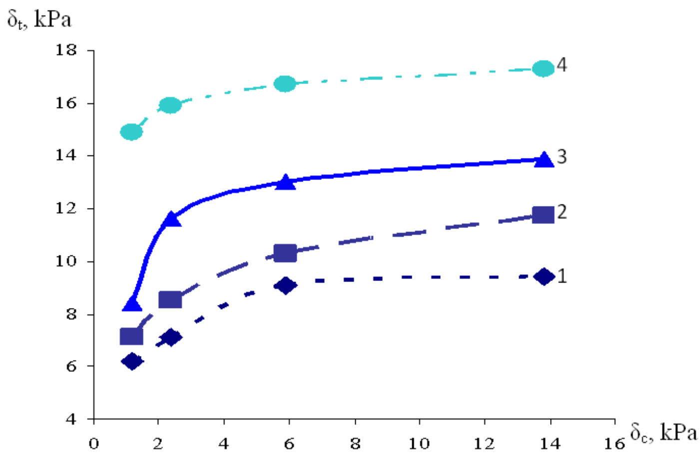

Fig. 4. Strength curves of sand with Na-CMC binder:
1 – 0.5 %, 2 – 0.8 %, 3 – 1.5 %, 4 – 5 %

Fabrication of films and estimation of their properties were performed in accordance with previously developed procedure applied for estimation of properties of solutions of regular substituted sodium carboxymethyl cellulose [13, 14, 15].

The experimental results (Table 1) were rather contradicting: on the one hand, such films made of low-substituted sodium carboxymethyl cellulose were sufficiently stable with relatively high mechanical strength, however, ont the other hand, they have poor elasticity, which is confirmed by their tensile strength at break: not higher than 6.0 %.

Table 1. Tensile strength of films based on solution of low-substituted sodium carboxymethyl cellulose

Item No.	Substitution degree, units	Concentration of Na-CMC in solution, %	Tensile strength, N/m ^{2}	Tensile strength at break, %
1	0.5	0.7	6.9	4.9
2	0.6	0.8	7.2	5.1
3	0.8	0.8	7.4	5.3
4	1.0	0.8	7.7	5.1
5	1.2	0.9	8.8	6.0

Another issue of the work was study into hygroscopicity and water absorption of films based on solution of low-substituted sodium carboxymethyl cellulose (Table 2). Hygroscopicity was studied by means of holding of the obtained films in ambient air at relative humidity close to к 80 % [16]. During the experiment the humidity varied in the range from 75 % to 85 %, caused by daily weather variations. Water absorption was estimated by wetting of the films in tanks with distilled water for 50 hours (slightly in excess of two days) at air temperature of 18°C--21°C.

Table 2. Hygroscopicity and water absorption of films based on solution of low-substituted sodium carboxymethyl cellulose

Item No.	Substitution degree, units	Hygroscopicity, %	Water absorption, %
1	0.5	20.2	298
2	0.6	20.4	315
3	0.8	20.5	338
4	1.0	20.9	365
5	1.2	21.2	396

The results of this stage of study into hygroscopicity and water absorption of films based on solution of low-substituted sodium carboxymethyl cellulose demonstrated that the considered parameters increase nearly linearly with increase in the salt substitution degree. Herewith, the influence of substitution degree on water absorption and hygroscopicity of films is nearly the same.

Such increase in hydrophilic performances of sodium carboxymethyl cellulose upon addition of minor amount of appropriate radicals is determined by redistribution of structural strength properties of hydrogen bonds at initial stages of etherification, which is characterized by increase in amount of relatively weaker hydrogen bonds.

Currently low-substituted sodium carboxymethyl cellulose in the range from 0.5 to 1-1.2 units is produced by chemical industry in sufficiently high amounts. This can be attributed to the fact that this salt is widely applied in petroleum,. textile, food, pharmaceutical industries, in production of detergents and so on as stabilizing, thickening, film forming agent [17].

Such situation significantly decreases expenditures for purchasing and use of sodium carboxymethyl cellulose, including the application as solution component for fabrication of dust suppression layers. The approximate financial analysis makes is possible to conclude as follows:

- average cost of Na-CMC is 6 rubles/kg ($0.1);

- in order to fabricate protective film with surface area of 1 m^2 overcoating dusting surface 0.0012 kg is required, that is, in order to overcoat the dusting surface area of 1 hectare 1.2 kg of Na-CMC is required, which is equivalent to 7.2 rub.

Therefore, if we compare this technology with application of latex film on dusting surfaces, this technology is less expensive by tens of times.

CLOSING REMARKS AND CONCLUSIONS

Bonding solution based on sodium carboxymethyl cellulose interacts with disperse particles and binds surface layer, thus preventing dusting and wind erosion of surfaces of technogenic dumps. Herewith, no impervious film coating is formed, characteristic for recipes including, for instance, latex. The protective layer is water- and air-impervious, does not impair aeration of substrate surface, can promote vegetation. In this regard the method of dust suppression by means of Na-CMC solution can be recommended for wide scale application. The final conclusions are as follows:

- Majority of existing binders for fixation of dusting surfaces of waste technogenic dumps have a number of principal drawbacks, such as high cost, toxicity and high consumption rate.
- it is reasonable to apply the proposed unique method of dust suppression on waste technogenic dumps, it is based on coating of dusting surfaces with protective layer containing sodium carboxymethyl cellulose with its content in the solution equaling to 0.8 % Na-CMC on dry basis.
- It is established that increase in content of Na-CMC binder in excess of preset ratio increases insignificantly the efficiency of dust suppression, as well as strength and wind resistance properties of protective layer at significant expenditures.
- Protective films based on low-substituted sodium carboxymethyl cellulose are highly steady and possess relatively good mechanical strength, however, the elasticity of these films is rather moderate, which is confirmed by the index of elongation at breakage of these films: not higher than 6.0 %.
- Investigation into hygroscopicity and water absorption of protective films based on solution of low-substituted sodium carboxymethyl cellulose demonstrated that the parameters of interest increase in fact linearly with increase in the salt substitution degree. Herewith, the influence of substitution degree on water absorption and hygroscopicity is nearly the same.

ACKNOWLEDGMENTS

The work was supported by the Grant program of President of Russian Federation for young scientists and post-graduates.

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