THE USE OF VICIA FABA AS A NATURAL COAGULANT IN WATER CLARIFICATION

Dr. B.Bina,
Dept. of Environmental Health Engineering
University of Isfahan

Abstract

Powdered seed suspension of the Vicia faba have been proved effective as a primary coagulant to clarify a stable kaolinite suspension. A study of electrophoretic mobility showed the Vicia acts as an anionic polyelectrolyte. Vicia as primary coagulant was found to be able in removal of 99.2 percent turbidity. Bacterial cells removal of over 99% was achieved in the range 25-100 mg/L of Vicia dose. The coagulation efficiency of Vicia was found to be affected by certain physico - chemical factors. The effect of coagulation of E. coli and particles can be interpreted in terms of adsorption concepts.

Key Words

Natural plant coagulant. Vicia faba, Water treatment

Introduction :

In many developing countries, clean water has always been a major problem, especially for the rural poor. Many villagers, since they have no alternative, have to consume surface water, either from rivers or rain - fed ponds. The purity of these sources cannot be guaranteed.

There is common consent that adequate treatment of turbid and polluted surface water is a prerequisite for making water safe for human usage and that coagulation is the most promising technological method for this purpose. This is however, not a European invention stemming from the dawn of industrialization. Traditional practices of water clarification, using flocculating soil and plant materials have been recorded in Asia and Africa already hundreds and even thousands of years ago[1].

The Egyptians practiced a form of coagulation as early as 2000 years B. C., and described the use of Nirmali seed for water clarification[2]. In india several types of processed natural coagulants were developed and studied. Moringa seed, Nirmali seed, Lentils, Tamarind seeds, potatos, and drum stick seeds are a few among them[3].

Vicia faba, also known as faba vulgaris, belongs to the family Papilionceae (order ; Leguminales) and are the only one, but probably the most potent, of a considerable number of cultivated plants used for coagulation of water.

The spread of knowledge about suitable technologies for primitive water treatment and the process of adaptation to local circumstances can be traced from comparative studies. The shape or even name of a plant material has often been taken as a model for the transfer of methods from one country to another. In Africa, a Nile Valley tradition developed which clarified the high turbid waters of that river with cultivated beans a process which then spread from Egypt towards the central sudan[4]. The oldest recorded refer to the Nubians of Upper Egypt and the Northern sudan who used "Egyption beans" (Vicia faba).

A few studies reported in the literature on the coagulation efficiency of Vicia faba were carried out without due regard for various physico-chemical factors which affect it. However, the present study was invariably carried out under controlled laboratory conditions in order to investigate the effects of these variables.

Materials and Methods

There are numbers of factors which affect the coagulation of suspended particles. Many investigators have concluded that the effective control of these variables can be achieved under laboratory conditions using suspensions of known chemical composition[5, 6, 7]

A water of known composition may be made up from distilled water and kaolin clay suspensions. The nature and amount of turbidity may thus be controlled. Artificial water was made by dissolving calcium chloride ($CaCl_2$) and magnesium sulphate, ($Mg\ SO_4$) in distilled water, to produced a water with an approximate calcium concentration of 0.5 mmol/L and magnesium concentration of 0.3 mmol/L. Alkalinity was provided by the addition of soduim bicarbonate to produce an alkalinity of 200 mg/L $CaCo_3$.

The kaolin clay used had been shown by x-ray diffraction to be pure. The detailed of prepration was discribed before[8].

The original intention had been to prepare the Vicia in a similar manner to the Moringa seeds (The most effective and widespread natural plant coagulants). However, the Vicia proved to be much harder than the Moringa seeds and simple crushing in the mortar was not possible. The easiest method was to pulversie the Vicia (including the outer casing) in a domestic coffee grinder until a fine powder was produced. To prepare the stock solution, 1 g was simply dissolved in 100 ml of distilled water, stirred for a short time, and then strained through a muslin cloth.

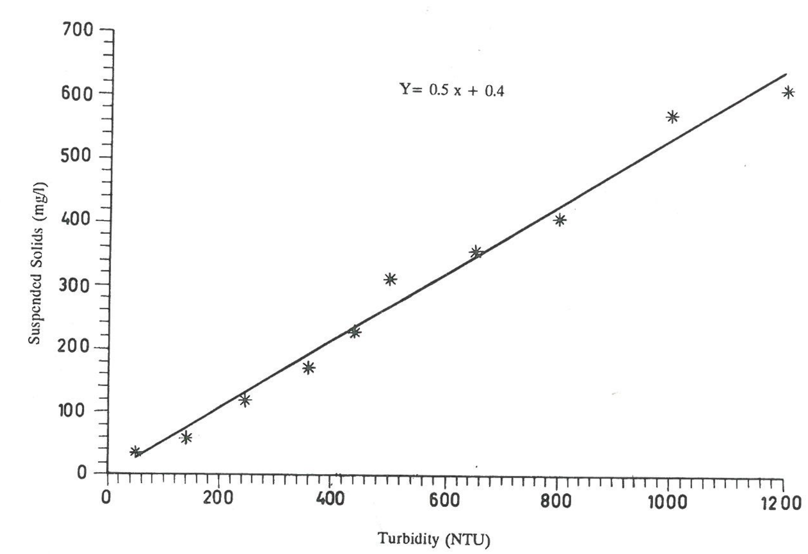
Conventional jar test experiments were carried out using a 4 jar test apparatus manufactured by Messers Patterson Candy International. Experiment procedure was described before[8]. Turbidity readings were carried out using a Hach model 2100 A turbidimeter.

A particle Micro-Electrophoresis Mark II, Apparatus, manufactured by Rank Brothers of cambridge, was used in this study.

Results and Discussion

An analysis of the suspended solids concentration for various kaolin turbidities was made and is presented in Fig. 1. In order to evaluate the efficiency of Vicia faba as a coagulant at different seasons three turbidity ranges (100 NTU, 300 NTU, 1200 NTU) were used.

Fig 1. Relationship Between Turbidity (Kaolin) and Suspended Solids.



Coagulation of Different Kaolin suspensions with Vicia

Table 1. shows the residual turbidity after 1 hour sedimentation with varying coagulant dose. The removal of the clay shows the higher the clay concentration, the more extensive is the removal. This indicates the significance of concentration of particles in that collision frequency is a function of the number of particles present in the system[9, 10].

The maximum removal was 99.25 at Vicia dose of 25 mg/L in high turbidity (1200 NTU). As it can be seen from the table the removal efficiecy of Vicia is considerably affected by the concentration of kaolin clay suspension. This was particularly so in water sample at lower kaolin concentrations (300NTU and 100 NTU).

However, it should be noted that significantly smaller quantities of this seed were required for optimum coagulation as compared to high effeicient Moringa oleifera seed.

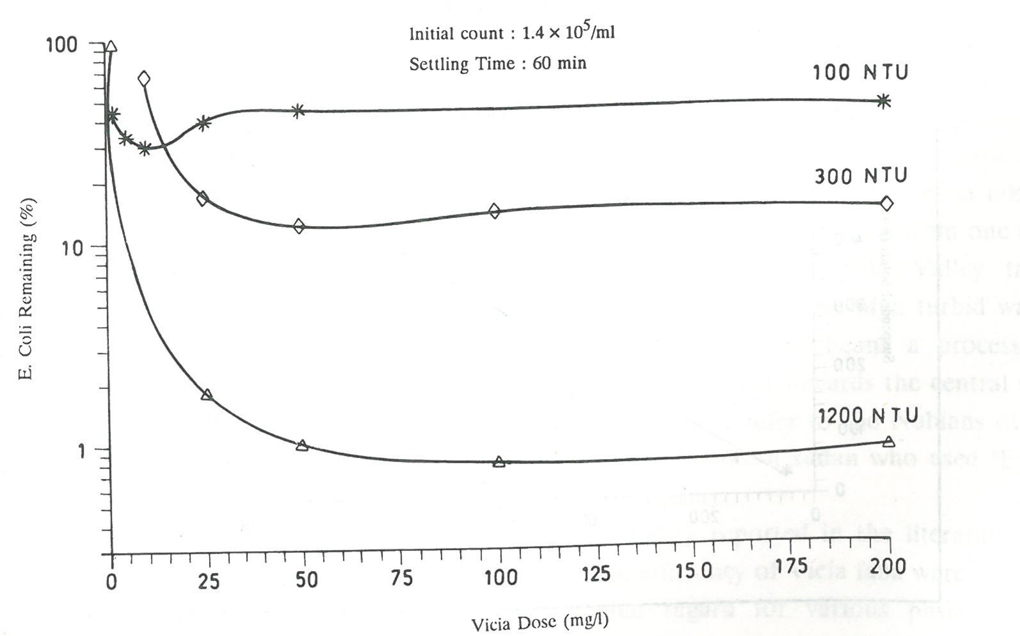
Removal of E. coli in Different Kaolin suspensions with Vicia

Fig 2. shows the effect of Vicia suspension on removal of E.coli after 1 hour sedimentaion. As it can be seen E. coli removal of over 99 percent was achieved during the first hour of sedimentation in water sample of high turbidity (1200 NTU). Lower reduction in number of E.coli was achieved at lower kaolin suspensions (300 NTU and 100 NTU). This may in part be due to the significance of removal due to collision[11,12].

Coagulant Dose (mg/L)	Turibidity Remaining (NTU)		
0	100	300	1200
5	25	120	--
10	20	80	65
25	28	20	9
50	35	15	38
100	--	55	70

Table 1. Removal of Different kaolin clay concentrations (100, 300 and 1200 NTU) With Varying Vicia Doses

Fig 2. Removal of E. coli in Different Kaolin Suuspensions With Varying Vicia Doses.



It was found that the data obtained on the removal of E.coli and kaolin fitted the Langmuir equation and plotted on a straight line (Fig. 3). All data was obtaind from coagulation and 1 hour sedimentation. The analysis of the results indicates that the bacteria and kaolin clay are affected in the same way by adsorption. The very close agreement of the adsorption for the kaolin and bacteria may be duo to the their similarity or because they soon become coated with Vicia suspension. It also shows the mineral particles can be used instead of microbial cells.

Electrophoretic Mobility Study

Figure 4. shows the effect of Vicia suspension on the zeta potential of kaolin and E.coli. The original zeta potenial (ZP) of the E.coli suspension was -20mv and that of kaolin was - 30 mv. These results fall into the range for raw surface water colloids, usually 12mv to -40mv[13]. Gradual addition of Vicia suspension increase the zp on the negative side. Being and anionic polymer, the negative zp of the colloidal suspension is increased when the optimum dose of Vicia seed suspension is exceeded. It is not zp, but the colloidal adsorption and bridging that plays an important part in coagulation with anionic polymers such as the Vicia suspension.

As the comparison the figure also shows the effect of Moringa oleifera seed suspension which is known as a cationic polyelectrolyte. As it can be seen addition of Moringa reduced zp to zero and then zp increased to positive after a Moringa dose of 200 mg/L. Moringa seed suspension would initially neutralize the colloids and after the negative charge is neutralized, the colloids would assume the positive charge of Moringa suspension. This is reflected in the progressive charge reversal. This difference in behaviour also shows the difference in the mechanisms of coagulation of these two coagulants.

Effect of Calcium Ion Concentration on Coagulation of Kaolin and E. coli with Vicia Suspension

It has been shown by Black. (1960)[7] that the presence of divalent cationic can greatly increase the ability of anionic polyelectrolytes to aggregate negative colloids. Investigations into the effect of calcium can be used to compare the behaviour of Vicia as an anionic polyelectrolyte and Moringa seed suspension as a cationic polyelectrolyte.

Fig 3. Bacteria and Kaolin (1200 NTU) Adsorption - Langmuir

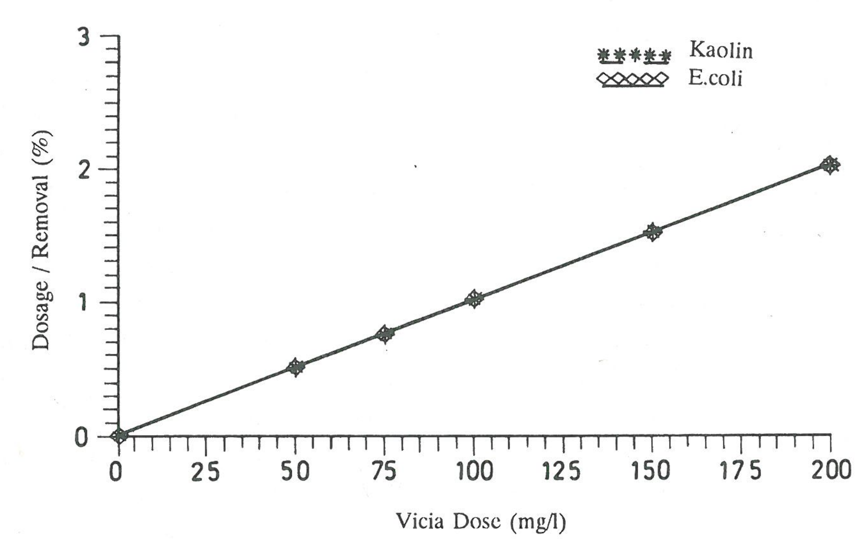
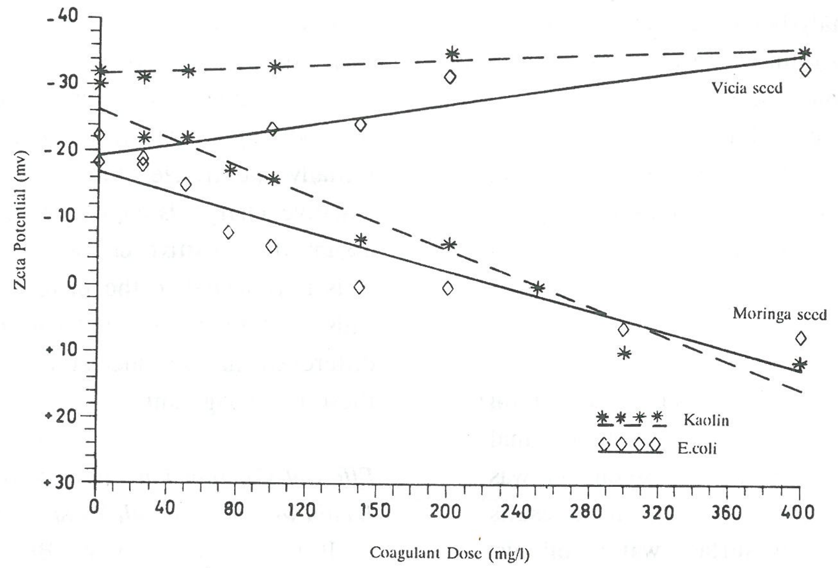


Fig 4. Effect of Moringa and Vicia on Zeta Potential of Kaolin (300 NTU) and E. coli suspension.



Calcium chloride ($CaCl_2$) was added to the samples to give calcium ion concentrations of 0, 25, 50, 75, and 100 mg/L respectively.

The Figure 5 shows that the Vicia was incapable of causing any reduction in the medium turbidity (300 NTU) water sample (distilled water with add alkalinity, 200 mg/L). The effect of calcium ion concentration on coagulation of kaolin and E.coli with Vicia suspension was much more significant than on Moringa. As it can be seen the removal of turbidity increased with increasing dose of calcium ion (Fig 5). According to Black[7] divalent calcium ions may affect anionic polymer clay systems in the following ways:

a. By compressing the thickness of the double layer of clay particles, thereby reducing interparticle repulsive forces.

b. By reducing interactions between polymer molecules adsorbed on clay particle surfaces.

The role of complex formation, Principally with calcium, was investigated in the flocculation of negatively charged sols with anionic polyelectrolytes[1 4]. Flocculation occurs from adsorption of polymers on the colloidal surface and from bridging of polymer chains between solid particles, if an appropriate content of an electrolyte is present. Complex formation occurs in the vicinity of the sol's surfaces between the counter ions and functional groups of the polyelectrolyte. This mechanism apparently plays a major role in the attachment of anionic polyelectrolytes to negative hydrophobic sols. The above theory can be applied to the results obtained from this experiment with Vicia as an anionic polyelectrolyte. A similar results was reported in another study using a natural anionic polyelectrolyte (Nirmali seed) as a primary coagulant[15].

Effect of pH on Coagulation with Vicia

To determine the optimum pH of the coagulant a mixture of E.coli and kaolin was prepared. pH was controlled by addition of 0.1N H_2SO_4 or 0.1N NaOH. The amount of acid or alkali required was determined by prior experiment so that after addition of Vicia suspension the desired final pH 5 to 10 was achieved. Turbidity and E. coli measurements were carried out after 1 hour sedimentation.

The effects of pH on the coagulation is shown in Figure 6. It can be seen from Figure the adsorption of E.coli and kaolin to Vicia was not significanlty affected over the pH range 7-6.

Fig 5. Effect of Calcium ion Conc. on Coagulation of E. coli and Kaolin (300 NTU) with Moringa and Vicia Suspension.

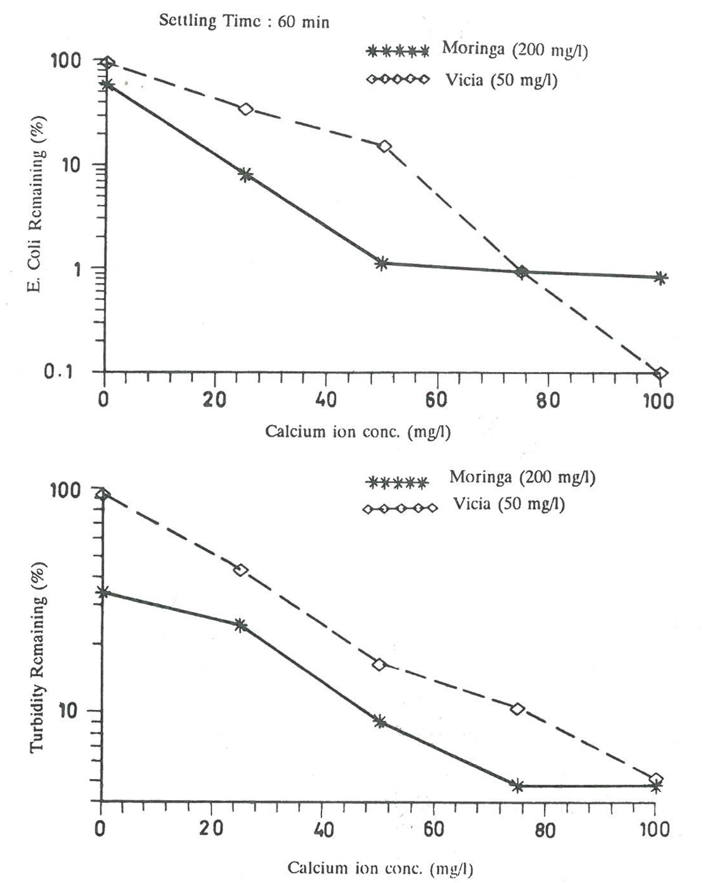
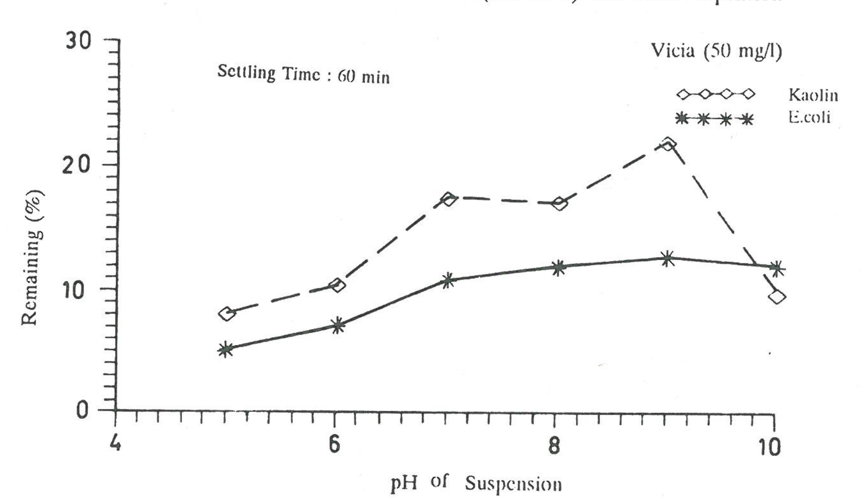


Fig. 6 Effect of pH on the Coagulation of E.coli and Kaolin (300 NTU) with Vicia Suspension



However, Vicia is a polyelectrolytes and coagulation of colloids takes place mostly by adsorption, pH is therefore not of very great importance. Tripathi (1976)[15] reported a similar effect of pH on removal of E.coli and kaolin by coagulation and flocculation with Nirmali seed extract (an anionic polyelectrolyte).

The high adsorption of Vicia at pH 5-6 may be due to the instability of colloid particles in suspension of low pH values. However, at pH 10 there is a possibility of production of calcium and magnesium hydroxide, because the artificial water used contains calcium chloride and magnesium sulphate, therefore coagulation may occur as results of precipitation.

Summary and Conclusions

1- From the results obtained in the present study it is possiple to conclude that the Vicia acts as an anionic polyelectrolyte.

2- The efficiency of Vicia suspension is unaffected over the range of pH that normally occurs in natural surface water.

3- It was found Vicia to be completely ineffective coagulant in very soft water. This inability to effect clarification in the absence of divalent calcium and magnesium is typical of an anionic polyelectrolyte

4- The removal of up to 99.2 percent turbidity and 1-3 log unit E.coli was obtained within the first 1-2 hours of coagulation with Vicia seed.

References

1- Jahn, S. A. A (1986). Proper Use of Africa Natural Water Coagulants for Rural Water Supplies. Publ. 117, GTZ.

2- Cohn, J. M., Rourke, G. A. and Woodward, R. L. (1958). Natural and Synthetic Polyelectrolytes as Coagulant Aids. J. Am. Wat. Works Assoc. 50, 493-478.

3- Suleyman, A., Muyibi,A., Evison, M.(1995). Moringa oleifera Seeds for Softening Hard Water. Wat. Res. vol 29, 4pp.

4- Jahn, S. A. A. (1981). Traditional Water Purification in Tropical Developing Countries. Publ. 117 GTZ.

5- Tenny, M. W. (1965). Chemical Flocculation of Microorganisms in Biological Waste Treatment. J. Water Pollut. Contr. Fed. 37, 1370-1388.

6- Stumm, W. & Morgan, J. J. (1962). Chemical Aspects of Coagulation. J. Am. Water Works Assoc. 54, 971-992.

7- Black, A.P. (1960). Basic Mechanisms of Coagulation. J. Am. water Works Assoc. 52, 492-501.

8- Bina, B. (1995). The Use of Moringa oliefera Seed as a Natural Plant Coagulant in Removal of Clay Particles and E.col. Water & sewage, vol. 14, 4-12.

9- Gemmell, R.S. (1963). Some Aspects of orthokinetic Flocculation. Ph.D. Thesis, University of Harvard.

10- Black, A. P. and Vilaret, M. R. (1969). Effect of Particle Size on Turbidity Removal. Am. Water Works Assoc. 61, 209-214.

11- O' Mellia, C.r. (1972). Coagulation and Flocculation. Physiochemical Processes for Water Quality Control, (ed. Wever W.J.) pp. 61-109. John Wiley & Sons, inc. New York.

12- Treweek, G. P. & Morgan, J. J. (1977). Polymer flocculation of Bacteria. J. colloid & interface Science. 60, 258-273.

13- Riddick, T. M. (1961). Zeta Potential and its Application to Difficult Waters. J. Am Water works Assoc. 53, 1007-1030.

14- Sommeraurer, A., Sussman, D. L. & Stumm, W(1968). The Role of Complex Formation in Flocculation of Negatively Charged Sols with an Anionic Polyelectrolytes. Kolloid Z. Polymere 222.

15- Tripathi, P. N, Chaudhuri, M. and Bokil, S. D, (1976). Nirmali seed-A Naturally Occurring Coagulant. Indian. J. Environ. Health, 18(4), 272-281.