Environment Protection Engineering

Vol. 14 1988 No. 3–4

M. FEROZE AHMED*

INFLUENCE OF pH AND SURFACE CHARGE ON DEWATERABILITY OF SEWAGE SLUDGE

An investigation of the change in dewaterability of sewage sludges due to the change in surface charges on sludge particles induced by the variation of sludge pH is reported. Electrophoretic mobility of sludge particles as a measure of surface charge and specific resistance as a measure of dewaterability were determined by adjusting pH of activated and digested sludges to the desired different values. A gradual reduction of specific resistance was observed with the lowering of pH until a minimum value representing the maximum dewaterability for each sludge was obtained at isoelectric point when no electrokinetic phenomenon was observed. A further reduction of pH caused a deterioration of dewaterability of sludges.

1. INTRODUCTION

Sewage sludge is an aqueous suspension of particulate solids composed of organic and inorganic matter. The pollution control programmes all over the world envisage the need for stringent effluent quality standards because of increasing wastewater volues caused by industrialization and rapid growth of population. Efficient treatment of a large volume of sewage and wastewater is associated with the production of a large quantity of sludge. The water content in most water and wastewater sludges ranges between 94 and 99.5%. The removal of water component results in the tremendous reduction in the bulk of the sludge and, consequently, in a greater reduction in the cost of handling and transportation. In spite of high water content, sludge dewatering still remains one of the most serious problems in wastewater engineering.

The stability of sludge particles in water is caused by high surface charge and low effective density. Sewage sludge dewatering is a difficult problem due to a complex nature of sludge particles regulated by the polymeric materials of natural origin

* Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

composed mainly of proteins and polysaccharides placed on the surface of the particles. The ease with which water may be removed from sludges by various methods largely depends on the state of aggregation of solids which, in turn, depends on surface charge. In fact, sludge particles carry a negative surface charge produced by direct ionization of certain ionogenic functional groups of proteins and other macromolecules present on the surface of the particles. Surface charge is, therefore, dependent on the pH of the surrounding media of the sludge particles.

Specific resistance to filtration and capillary suction time (CST) are the parameters widely used to express dewaterability of sludges conditioned by various processes. COACKLEY [1] first observed the reduction of specific resistance to filtration by lowering the pH of sewage sludge to 4.7. He also reported that further lowering of pH to 1.1 had not such a great effect on the dewaterability improvement. GENTER [6] observed that the optimum pH for conditioning and dewatering elutriated sludge was 4.7, which according to him corresponded with the average isoelectric point of the sludge. EL-HATTAB [3] found that specific resistance decreased with the lowering of the pH value of sewage sludge. EVERETT [4], KARR and KEINATH [8] observed the reduction of specific resistance to filtration with the lowering of the pH value of digested and activated sludges by adding sulfuric acid.

Although many investigators have found the improvement of dewaterability of sewage sludges with the lowering of pH value, the relationship between dewaterability and surface charge of sludge particles which is regulated by pH was not clearly understood. The surface charge, usually measured by electrophoretic mobility of the particles in an electric field, represents a fundamental characteristic of the surface of the particles. The purpose of this study was to make a quantitative evaluation of change in sewage sludge filterability due to variation of surface charge of sludge particles induced by the change in pH of the sludge.

2. EXPERIMENTAL WORKS

The use of specific resistance to filtration in the assessment of dewaterability of sewage sludges is well recognized, while electrophoretic mobility of sludge particles is a measure of surface charge and surface potential. Since surface charge of sludge particles depends on the pH of the surrounding media, electrophoretic mobility and specific resistance were measured by lowering the pH value of the sludge by adding 6M HCl and increasing it by 6M NaOH. Large number of activated and digested sludge samples were made in the laboratory by adding a few drops of acid or alkali, depending on the desired pH value. The samples were then stirred slowly using electrically operated paddled stirrer at 25 rpm until the gas production ceased and a constant pH value for each sample was obtained. Sludge samples treated with NaOH became darkish in colour, and at high pH values a thick gelatinous mass of dark sludge was obtained.

The specific resistance r was computed using the filtration equation:

$$\frac{t}{V} = \frac{\mu rc}{2PA^2} V + \frac{\mu R_m}{PA} \tag{1}$$

where V is the volume of filtrate obtained at time t, P and A are the applied pressure and filter area, respectively, R_m is the resistance of the filter medium, c and μ are concentration of solids in the sludge and viscosity of the filtrate, respectively.

Filtration experiments were carried out to find out the volume of filtrate V and the corresponding time t using the Buchner funnel filtration apparatus shown in fig. 1.

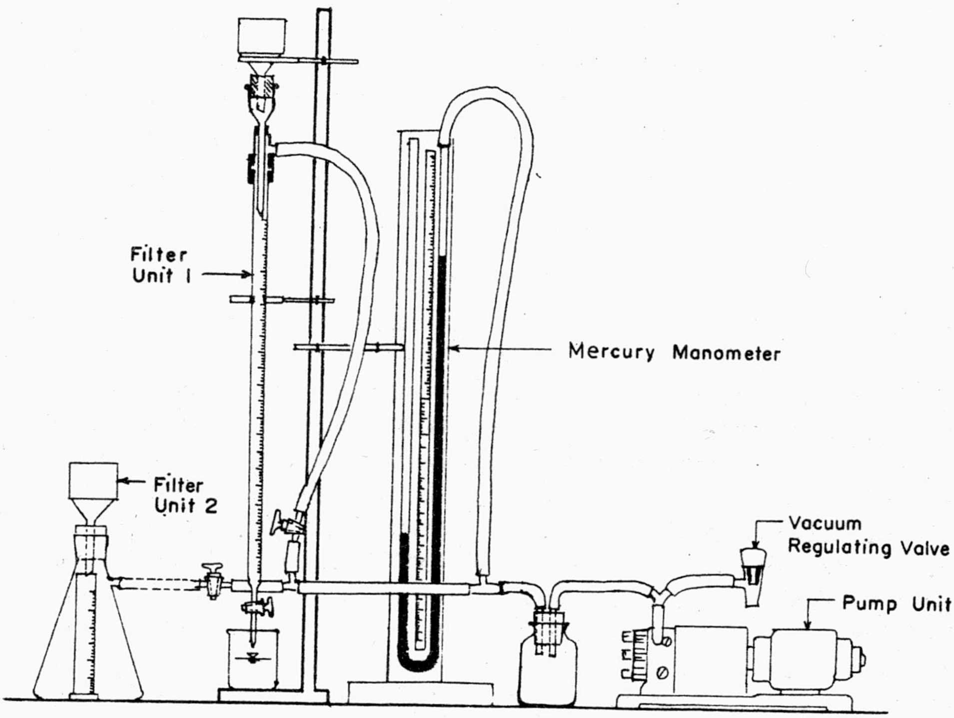


Fig. 1. Buchner funnel filtration apparatus

The unit equipped with a burette was used for the filtration of difficult sludge, where accurate measurement of the volume of filtrate was necessary. The second unit, having a measuring jar in a conical flask, was used where the rate of filtrate flow was very high and the total volume of filtrate exceeded the capacity of the burette. A Whatman No. 1 filter paper was used as filter medium and the standard filtration pressure of 49 kPa was maintained in the vacuum filtration of each sample.

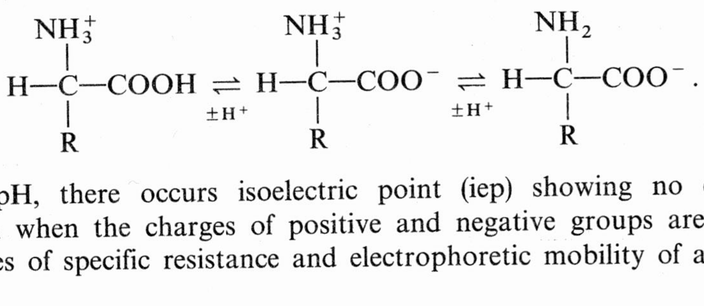
Electrophoretic mobility of sludge particles was determined using particle electrophoresis apparatus MKII of Rank Brothers, England. Individual particles in a sludge sample placed in an electrophoresis cell were not visible as the light could not pass through particle packed sludge media. The particles present in a few drops of sludge were suspended in the filtrate collected from the same sludge and the suspension was poured into the flat cell of the apparatus for the observation of individual particles. The velocity of particles was observed under the applied voltage gradient by reversing the polarity of the electrodes in the alternate observations. The particle velocity was computed from the mean of twenty observations timed on two stationary levels. The accuracy of electrophoretic mobilities measurement by microscopic method has been determined by SHAW [10]. He concluded that the probable error for an electrophoretic mobility calculated from the mean of twenty velocity measurements would amount to about 1.5 to 2%.

The electrophoretic mobility of sludge particles for pH values below 2.0 could not be determined due to a rapid formation of gas at the electrodes. As soon as the voltage was applied, accumulating gas at the electrode brought about a complete instability in the content of the cell showing a very high and erratic velocity of the particles.

3. RESULTS AND DISCUSSION

The t/V versus V plots of digested sludge adjusted to various pH values have been shown in fig. 2 by a family of straight lines. It may be seen that the slope of the lines, which according to eq. (1) is directly proportional to specific resistance, gradually decreases with the lowering of pH and attains a minimum value at pH 2.1. A further reduction in pH did not show any improvement of dewaterability, the slope of t/V versus V plots rather increased at pH values lower than 2.1. On the other hand, the slope of the lines becomes gradually steeper when the pH of the sludge is increased due to the addition of NaOH. At pH 11.8, the line becomes almost vertical showing a great increase in specific resistance to filtration.

Ionization of acidic and basic groups of proteins in digested sludge accounts for some of its properties. COACKLEY [2] in his study on dewatering of sewage sludges found that sludge particles behave like particles covered with protein. The variation in ionization of amino groups and carboxyl groups of amino acids with the concentration of hydrogen ions may be illustrated as follows:



At certain pH, there occurs isoelectric point (iep) showing no electrokinetic phenomenon when the charges of positive and negative groups are equal.

The values of specific resistance and electrophoretic mobility of activated and

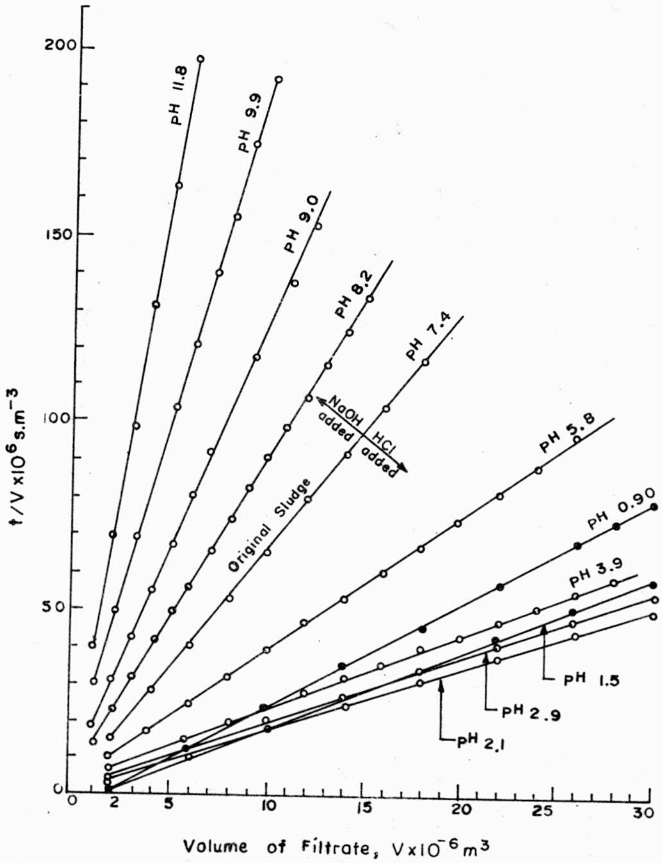


Fig. 2. Filtration of digested sludge adjusted to various pH values

digested sludges are plotted against pH values in fig. 3. It may be observed that the isoelectric point of digested sludge was at pH = 2.6. The results show that the specific resistance to filtration of each sludge decreased gradually with the lowering of pH value up to isoelectric point, when a minimum value of specific resistance representing the maximum dewaterability was obtained. Further reduction of pH caused the deterioration of dewaterability of the sludge. ROBERTS and OLSSON [9] studied the dewatering of activated sludge with polyelectrolyte and found that the minimum CST corresponded to the amount of polyelectrolyte required to obtain zero charge on the anionic colloidal particles in the sludge. Sludge samples treated with NaOH became difficult to filter, and at a very high pH value a thick mass of practically unfilterable sludge was obtained. HATFIELD [7] observed a sharp increase in a specific resistance at pH above 7.0, while the sludge acquired a gelatinous form. KARR and KEINATH [8] found that the dewaterability of activated sludge at pH = 11.0 was extremely poor.

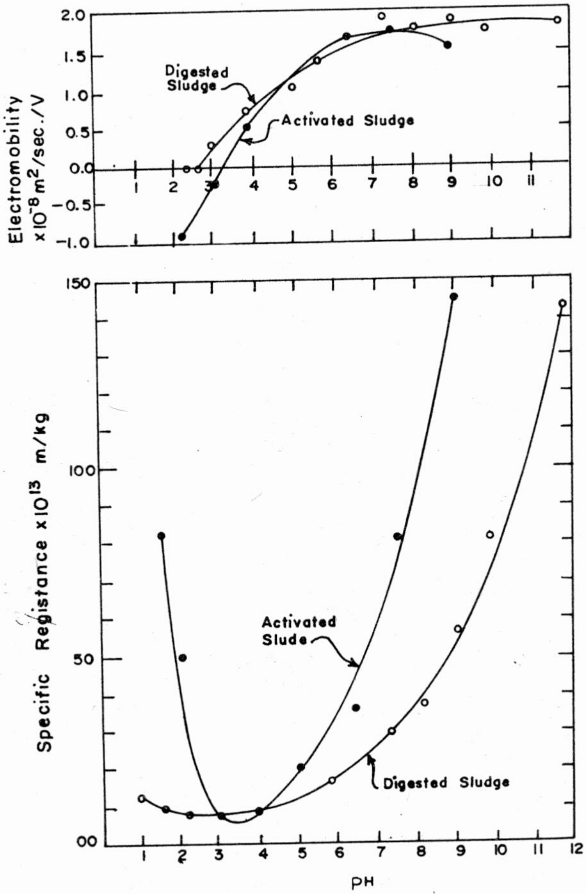


Fig. 3. Variation of specific resistance and electromobility of activated and digested sludges with pH values

The results indicate that the improvement of dewaterability of sewage sludges at lower pH values was due to destabilization and aggregation of colloidal particles. Sludge particles, under microscopic examination, were found to be present in the maximally flocculated form at isoelectric point. Aggregated particles in the filter cake have less surface area to produce resistance to flow of filtrate. The results presented in fig. 3 show that the activated sludge is very sensitive to pH change. A sharp increase in specific resistance at pH below isoelectric point clearly indicates the restabilization of sludge particles due to high positive surface charge on particles. An increase in the specific resistance of digested sludge at very low pH indicates the occurrence of charge reversal, although the presence of positive charge on digested sludge particles has not been definitely shown due to gas formation at the electrode in digested sludge liquor at low pH.

The study reveals that the specific resistance to filtration of activated and digested sludges can be greatly reduced by lowering the pH value to isoelectric point. A further reduction could not be achieved, probably due to the high bound water content in the sludge particles which inhibited their aggregation. It was found that bound water content increased with lowering the pH up to 2.5 and then sharply decreased at pH equal to 2.0. Flocculation and breakdown of flocs might be responsible for the observed variation in bound water content of sludge particles.

GALE [5] suggested for specific resistance the value of 0.1×10^{13} m/kg to represent a good filterable sludge. Hence, the minimum values of specific resistance shown in fig. 3 obtained by only pH adjustement are not considered to be low enough when compared with the specific resistance of a well conditioned very well filterable sludge. A further reduction of specific resistance, which is required, can probably be achieved by destroying the water holding properties of sludge particles and promoting aggregation of fine and small particles into stronger flocs.

4. CONCLUSIONS

The surface charge and surface potential of sludge particles regulated by the pH of the sludge exerted a great influence on dewaterability of sewage sludges. A reduction in surface potential due to pH lowering enhanced the aggregation of particles and caused an improvement in dewaterability. The minimum specific resistance representing the maximum dewaterability occurred at isoelectric point. Restabilization of sludge colloids due to positive surface charge at pH below isoelectric point resulted in an increase in specific resistance.

The increase in pH with the addition of sodium hydroxide produced a highly dispersed sludge of more gelatinous nature. As a result, the dewaterability of the sludges deteriorated tremendously at higher pH values. Activated sludge was found to be very sensitive to pH change. A small change in the pH of activated sludge caused a large change in its specific resistance.

The reduction of specific resistances of activated and digested sludges by pH adjustment to isoelectric points was significantly high, but the reduced values obtained by pH adjustment alone were not considered low enough when compared with the extremely low specific resistance required for economic filtration of sewage sludges.

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WPŁYW pH I ŁADUNKU POWIERZCHNIOWEGO NA ODWADNIANIE OSADÓW ŚCIEKÓW

Określono podatność osadów ściekowych na odwadnianie w zależności od zmian w ładunkach powierzchniowych cząstek osadów wywołanych zmianami pH. Oznaczono ruchliwość elektroforetyczną cząstek osadów (będącą miarą ładunku powierzchniowego) oraz oporność właściwą (będącą wskaźnikiem podatności osadu na odwadnianie). Zbadano osad czynny i przefermentowany zmieniając odczyn do żądanej wartości. Zaobserwowano, że wraz z obniżaniem pH osadu stopniowo zmniejsza się oporność właściwa. W punkcie izoelektrycznym (kiedy nie obserwuje się zjawiska elektrokinetycznego) jest osiągana minimalna wartość pH odpowiadająca maksymalnej podatności osadu na odwadnianie. Dalsze obniżanie pH powoduje pogarszanie podatności osadów na odwadnianie.

ВЛИЯНИЕ pH И ПОВЕРХНОСТНОГО ЗАРЯДА НА ОБЕЗВОЖИВАНИЕ ОСАДКОВ СТОЧНЫХ ВОД

Определена податливость осадков сточных вод к обезвоживанию в зависимости от изменений в поверхностных зарядах частиц осадков, вызванных изменениями pH. Определили электрофоретическую подвижность частиц осадков (будущую мерой поверхностного заряда) и удельное сопротивление (будущее показателем податливости осадка к обезвоживанию). Исследовали активный и сброженный осадки, меняя их реакцию до требуемого значения. Наблюдали, что вместе с понижением pH осадка постепенно понижается удельное сопротивление. В изоэлектрической точке (когда не наблюдается электрокинетическое явление) достигается минимального значения pH, отвечающего максимальной податливости осадка к обезвоживанию. Дальнейшее понижение pH вызывает ухудшение податливости осадков к обезвоживанию.