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Study on the Treatment of Wastewater in Tunneling with Joint Use of Cement and Aluminum Sulfate

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***Abstract*—Based on the self-purification characteristics of wastewater in highway tunneling, this paper analyzed the causes and mechanism of its formation. It is found that there are some components of coagulants in protecting gunite for wastewater treatment. From experimental study, a method of treating wastewater in tunneling with joint use of cement and aluminum sulfate is put forward. The method is especially effective in the treatment of toxic nitrobenzene, with a removal rate as high as 60%. This method is suitable for highway and railway construction due to its characteristics of existence of many construction spots and convenience of material so that it has a fairly good application prospect.**

Keywords: wastewater in tunneling; cement; coagulant; nitrobenzene

With the development of highways and railways in China, the scale and number of tunnels and their construction scales are increasing continuously. Construction of tunnels results in a large quantity of wastewater, which mainly consists of muddy water produced during excavation, boring, construction of continuous retaining walls and application of shields, water for eliminating dusts after blasting, water seeping out from gunite, and wastewater during mixing and that drained out from prefabricating plants, besides muddy gushing water when tunneling encounters poor geological sites, as well as fissure water in bed rocks[1-3]. Because of the use of mechanic equipment and emulsified ammonpulver in tunneling, the wastewater contains such pollutants as nitrate, CODcr, SS petroleum wastes, in addition to nitrobenzene in excess of limit resulting from blasting[4].The wastewater in tunneling, therefore has become a major target in environmental protection. The wastewater in tunneling, therefore, has become a major object of treatment in environmental protection in construction of a tunnel. Owing to the characteristics of wastewater in tunneling, method of coagulation is generally used home and abroad due to its low cost[5-7]. Because of the variety in quality and quantity of wastewater in tunneling, as well as the difficulties in determination of the capacity of a regulating tank, a large amount of coagulant is consumed and wasted. Based on experimental study, common cement in construction is used in this paper for the sake of the use of local material. The cement is mixed with aluminum sulfate to study their joint treatment effect, which is of significance in the reduction of cost in the treatment of wastewater in tunneling.

I. Water Quality and Method in Experiment

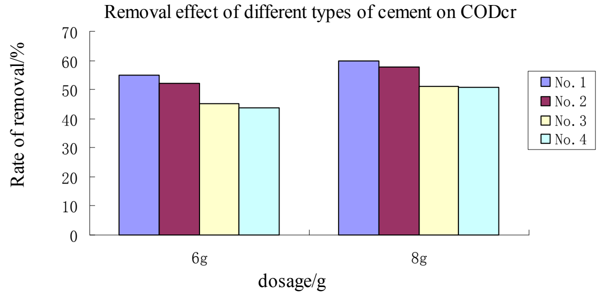
Based on the actual quality of wastewater in tunneling, water sample in the experiment was obtained by mixing of clay, oil, nitrobenzene, etc., with CODcr controlled in the range of 100~200mg/L, oil in the range of 50~100mg/L and nitrobenzene in the range of 5~70mg/L.

Sextuplicate mixers and 500ml beakers were adopted in the experiment with 400ml of water sample taken. After a selected coagulant was added in a solution, it is mixed thoroughly for 10min at a rotational speed of 120-180rounds/min, then allowed to stand for 40min, and the clear solution was taken for testing.

II. Experimental Results and Discussion

A. *Effect of types of cement on flocculation*

The original water with 130mg/l CODcr and 68mg/l nitrobenzene was prepared manually. 6 grams and 8 grams of cement of popular brands, such as Jidong(No.1), Hailuo(No.2) and Qinling(No.3), and discarded cement(No.4,after unsealed and kept in open air for about a year, still in power) were taken, and respectively added to 400ml of waster sample, with the mix stirred rigorously for 10 minutes, then was allowed to stand for 40 minutes. The clear liquid was taken for testing, with the treatment effect of each cement on CODcr and nitrobenzene shown in Fig.1.



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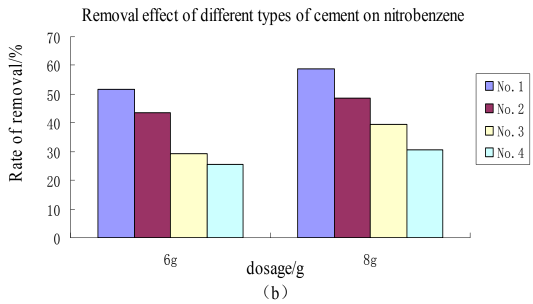


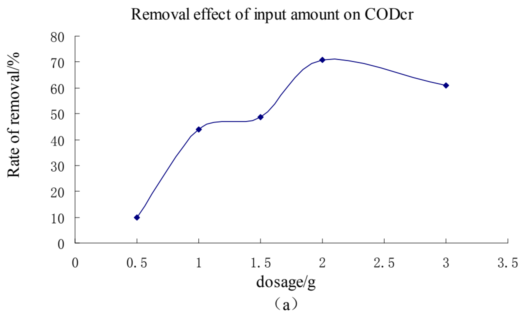
Figure 1. Removal effect of different of cement

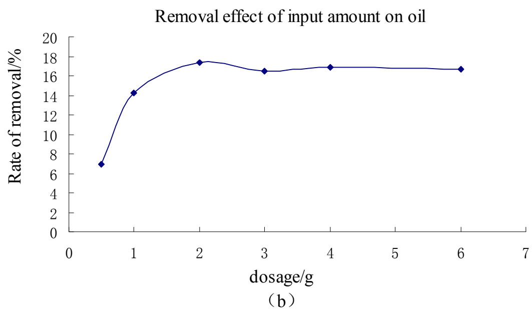
It can be seen from Fig.1 that each cement has certain treatment effect of wastewater in tunneling, with removal rate of CODcr in a range of 42~60% and that of nitrobenzene in a range of 20%~60%, though different cement has different outcomes. In consideration of practicability and extensiveness of the application of experimental results, in the following experiment, the discarded cement in construction sites was used to further study the treatment effect.

B. Flocculation effect of cement and its use

1) Coagulation effect of cement on single pollutant

The coagulation effect of cement on various individual pollutants is as shown in Fig.2.





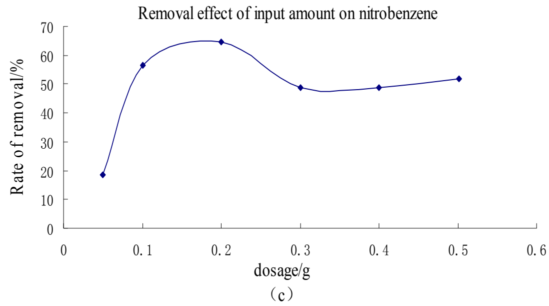


Figure 2. Removal effect of cement on individual pollutants

It is evident from Fig.2 that with the increase of quantity of cement, the removal rate ascends faster in the beginning and slows down gradually. This is because the increase in the amount of cement enhances the flocculation of pollutants, but with excessive amount of cement added, the concentration of cement in the resulting cement gel was so high as to block the adsorption of pollutants onto reticulated structure of the gel. There is a large difference in the optimum amount of cement for different pollutants, and with the optimized amount of cement of 0.2g, 2g and 2g added for nitrobenzene, CODcr and oil respectively, and corresponding removal rate of 60%, 70% and 18%.

2) Comparison with the treatment effect of common coagulants

With the optimum quantity of cement, the treatment effect of cement and that of common coagulants is compared in Table I.

From Table I it is clear that commonly used coagulants have no marked advantage as compared to cement. Though the removal effect of cement on CODcr is inferior to that of aluminum sulfate, it is superior to ferric chloride; The removal rate of nitrobenzene with cement is lower than with aluminum sulfate, ferrous sulfate or ferric chloride; the removal rate of oil with cement is less than that with aluminum sulfate or ferric chloride, but higher than with ferrous sulfate. So in general, cement has fairly good effect of flocculation, if used jointly with some common coagulants, better effect can be expected.

TABLE I. COMPARISON BETWEEN CEMENT AND SOME COMMON COAGULANTS

Index	**Removal rate of CODcr (%)**	**Removal rate of nitrobenzene (%)**	**Removal rate of oil (%)**
cement	39.1	12.6	10.9
aluminum sulphate	54.8	28.6	15.2
ferrous sulfate	10.1	24.0	6.8
ferric chloride	10.2	21.2	11.6
Note: concentration of original water(mg/L)	93.8	16.0	6.4

From the comparison of the removal effect with joint use of aluminum sulfate, ferrous sulfate and ferric chloride respectively with cement, it is found that the effect is higher for their joint use than that when they are used individually.

C. Optimum parameters for joint use of cement and aluminum sulphate

1) Proportion of cement and aluminum sulphate

With 3g of cement, ratios of cement to aluminum sulfate of 10:1, 15:1, 20:1, 25:1, 30:1, 35:1 and 40:1 respectively, the removal rates of CODcr, oil and nitrobenzene are as plotted in Fig.3. From Fig.3, it can be seen that a ratio of 25:1 between cement and aluminum sulfate attains the optimum removal rate, i.e., 60%, 80% and 30% for nitrobenzene, CODcr and oil respectively.

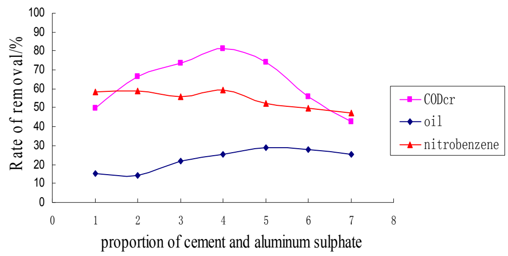


Fig.3 Removal rate of CODcr, nitrobenzene and oil with different proportion of cement to aluminum

2) Effect of reaction time and thoroughness of stirring

With 3g cement and a ratio of 25:1 between cement and aluminum sulfate, and 2h of sedimentation, the effect of the number of rounds of stirring on treatment effect is plotted as shown in Fig.4, and that of the sedimentation period is as shown in Fig.5.

From Fig.4 and Fig.5, and comprehensive consideration, the optimum rotational speed and sedimentation period are 150r/min and 60minutes respectively. With these optimum experimental parameters, the treatment results are listed in Table II, from which it can be seen that the resulting water quality attain class 1 standard for the discharge of wastewater as stipulated in GB 8978-1996.

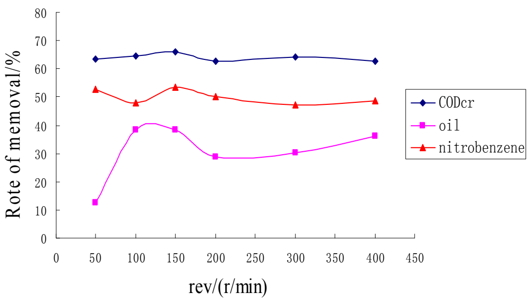


Fig.4 Removal rate of CODcr, nitrobenzene and oil with different rotational speed

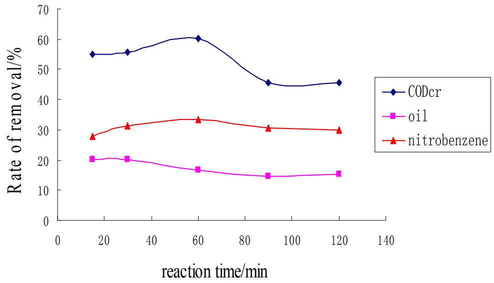


Fig.5 Removel rate of CODcr, nitrobenzene and oil with different reaction period

TABLE II. TREATMENT RESULT UNDER OPTIMUM EXPERIMENTAL CONDITIONS

Index	Proportion (cement:aluminum sulfate=25:1)	Rotational speed (150r/min)	Sedimental period (60 min)	Concentration -nbe Fore-treatment (mg/l)	Concentration after treatment (mg/l)
Removal-rate of CODcr (%)		69.5		176.7	53.9
Removal-rate of notrabenzene (%)		55.2		4.4	2.0
Removal-rate of oil (%)		20.3		12.5	9.9

III. AVAILABILITY OF SEDIMENT AFTER WASTEWATER IN TUNNELING WITH JOINT USE OF CEMENT AND ALUMINUM SULFATE

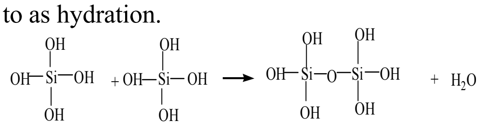
It is found from experiment that with cement and aluminum admixture as a coagulant, the treatment effect is generally better than that by using an individual coagulant; during coagulation, there are larger blocks of floccules and fast sedimentation; and after sedimentation, agglomeration and solidification are rarely seen at the bottom of a sedimentation tank, which eases the cleanup of sludge and ensures the capacity of the tank. Cement used in the experiment is the major component of a treating agent of wastewater in tunneling so that the dosage of aluminum sulphate is greatly reduced, resulting in a save of cost. For cement is a popular building material, it cannot cause any problem of secondary contamination to waterbodies.

For deposit at the bottom of a sedimentation tank after treatment jointly with cement and aluminum, it can be used in the construction of a highway or the embankment of a railway, or be buried at a waste disposal area because no harmful substances are added during the treatment and the deposit mainly consists of solid concrete.

IV. COAGULATION MECHANISM OF CEMENT

In wastewater treatment the major inorganic coagulants are aluminates, ferric salts and a mixture of the two, and the commonly used include Portland cement (with calcium silicate as its major hydraulic substance), alumina cement (with calcium aluminate as its major hydraulic substance) and sulfate aluminum cement (with calcium sulfoaluminate as its major hydraulic substance), etc.. In tunnel construction, the commonly used one is Portland cement, whose clinker mainly consists of CaO, SiO_2, $A1_2O_3$ and Fe_2O_3. Its aluminum and ferric compounds can be effective for flocculation in an aqueous solution. CaO acts with water, which produces deposit of $Ca(OH)_2$, causing flocculation, besides the effectiveness of SiO_2.

SiO_2 represents the component of silicate in cement. Silicic acid is a weak acid, which can create orthosilicic acid in water, and various polysilicates can be produced by the coagulating effect of the latter. This process involves the dehydration and formation of silicon-oxygen bond, and is referred to as hydration.



During hydration, fine particles of cement (C_3S, C_2S, C_3A and C_4AF) form various hydrates after a series of chemical and physical processes of decomposition, diffusion and dissolution. After water and cement are mixed for a few minutes, a gel membrane consisting of CSH colloid and CH crystal is formed. Water permeates into the membrane, which increases osmotic pressure to such a level as to break the membrane and let water continuously permeate into it. In this way the outside water gets in contact with hydrated cement particles, resulting in new gel. On one hand the gel makes the original membrane thicker so as to slow down the hydration, on the other hand, it enters the aqueous solution, interconnecting the cement particles. This process goes on continuously so that the membrane becomes thicker and thicker until reticulate gel structures are formed outside the membrane[8]. During the formation of the gel structures, the pollutants are also adsorbed.

V. CONCLUSIONS

From the field investigation at construction sites of tunnels, the wastewater from tunneling has a significant effect on aquatic environment so that efficient measure should be taken for its treatment. Both phenomenon in tunnel construction and experimental study indicate that various brands of cement in the market and discarded cement have a certain effect in the treatment of wastewater during tunneling. There is no marked difference in the removal effect of CODcr, nitrobenzene and oil between the use of cement and common coagulants; if cement is jointly used with other coagulants better result can be obtained, with cement plus aluminum sulfate producing the best outcome; with a proportion of cement to aluminum sulfate of 25:1, the removal rates of CODcr, nitrobenzene and oil are as high as 80%, 60% and 20% respectively. On a construction site, because of the popularity of cement, it can be generally used as a coagulant, which is low in cost, simple in operation, hence applicable in highway and railway tunneling with the existence of many construction spots and ease in the availability of materials so that it is expected to be widely adopted in practice.

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