A Novel Biological Method for Sludge Volume Reduction by Aquatic Worms

Yalda Basim, N. Jaafarzadeh, and M. Farzadkia

***Abstract*—The application of biological methods of sludge reduction and treatment, compared with mechanical and chemical methods, due to the lack of secondary pollutions has attracted more attention in recent years. The present research studies the reduction amount of suspended solids in the waste of the activated sludge by an aquatic worm (*Lumbriculus variegatus)* in wastewater treatment plant and total amount of suspended solids in the worm reactor with different dissolved oxygen concentration. According to the results, the average reduction of suspended solids in the sludge of different oxygen contents doesn't make difference statistically, and its obtained maximum reduction equals to 33%. The average reduction amount of 16% and 12% which have been under observation in this parameter respectively show a noticeable change with regard to the reactors both in phase one and two. Therefore, the performance of the species of the aquatic worm in the reduction of sludge TSS is confirmed.**

***Index Terms*—Aquatic worm, *Lumbriculus variegatus*, total suspended solids, waste sludge.**

I. Introduction

Sewage treatment was capable of producing a large amount of sludge. The high expense of sludge disposal options together with stringent environmental regulations provided impetus for investigating novel sludge reduction techniques [1]. The complete sludge processing chain involved the transport of large volumes which could be minimized by decreasing the amount of waste sludge [2].

A lot of research had been carried out on the reduction of disposed sludge by aquatic worms. Hendrickx and his colleagues were among Dutch researchers who compared the performance of a species of aquatic worms, called *Lumbriculus variegatus*, in a reactor with perforated media containing worms with a usual reactor without any worms. The result of this research reflected that the rate of TTS reduction in the reactor containing worms in most cases was three times greater than that of the reactor without worms [3]. In the other study designs, parameters were determined in an aquatic worms reactor [4]. A full scale worm reactor for efficient sludge reduction was studied and the results presented the reducing amount of sludge by at least 65% on TSS basis [5]. A study on worm biomass showed that it had a broader application potentials, such as feeding fish [6]. In other research on sludge reduction, through using an aquatic worms named *Limnodrilus hoffmeisteri*, the researchers found out that the worm population would exhibite a total sludge reduction rate of 297±10.1 mg TSS/L/d [7].

In addition, Huang and his collaborators studied the reduction of the sludge which was produced by activated sludge process by a species of aquatic worms called *Tubifex tubifex* in a reactor with returned sludge [8]. Furthermore, an ecological method regarding the use of four types of Micro-fauna for the reduction of waste sludge was surveyed by them. The results of this survey showed that the rate of reduction depended on the classification and body size of the micro-fauna. The species in the kingdom of Oligochaeta showed the highest efficiency in sludge reduction [9].

Wei and his colleagues, found out that worms, in terms of body size, were the biggest organisms in the sludge treatment cycle. Compared to Protozoa, they were easier to maintain, and due to body size, they had enough capability in sludge reduction [10]. Wei and Liu, both from China, designed a combined reactor for the reduction of sludge using both free-flowing worms and sessile ones. In this experimental reactor, the sludge TSS was reduced by 48 percent, which was mainly due to the presence of Tubificidea [11]. In Netherland, Rastak studied the possibility of reducing activated sludge in wastewater treatment plants using aquatic worms of Oligochaeta at experimental scales. In this research, the environmental factors affecting the performance of worms were surveyed. This research confirmed the use of worms as a protein-supply source in the food for fish and domestic animals [12]. The result of a study about mass balances and processing of worm faces showed that 39% of nitrogen and 12% of phosphorus in the sludge which were digested by the worm were used in the formation of new worm biomass, which had potential for reuse [13].

The objectives of this study were known as: identification of appropriate and endemic species of aquatic worm called *Lambriculus variegatus*, adaptation of life natural environment of worms to laboratory situations, determining the worm species performance amount in accordance with the sludge reduction in Ahvaz WWTP, and determining the effective environmental parameters on worm performance with a focus on DO (dissolved oxygen).

II. Materials and Methods

Providing the worms from the specified species was a chief concern in this research. Due to the possibility of availability of this species in areas with organic and decomposed materials, the probable residence of this species was located, samples were taken from the benthic materials of Khuzestan

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water reservoirs including Karoon River, Maleh Stream, Shadegun Wetland, and Dez river in Iran using grab model Van Vee [14]. Then microscopic pictures of the samples were taken and identified with "Freshwater Biology" [15]. In these surveys, no worm belonging to the subclass Lumbiculidae was observed. Next, the results of a field study which we came upon led to the sampling of springs in the Kermanshah Province in the west of Iran [16]. Finally, the species of Lumbriculus which was variegated from the Oligochaeta subclass and Lumbiculidae family [17] were found in the sediment deposits of Jabery and Ravansar springs in the Kermanshah Province. To maintain the environment of the collected warms as well as their compatibility with the new environment, the vessels containing worms were aerated via pumps and the temperature of the medium was constantly under control [14].

The reactor of the experiment contained 1500 mg in wet weight of the aquatic worm, and 100 milliliter of wastewater sludge of Ahvaz wastewater treatment plant which was taken daily according to periodical items A2 and B1060 according to standard methods for the examination of water and wastewater [18]. Its dissolved oxygen was regularly measured along the conducting of experiment. Also, the PH, the temperature, the total TSS of the incoming sludge and outgoing sludge were measured every 24 hours. Experiments were carried out in two steps with two different oxygen contents, and due to the minimum of the samples required, each step took eight days. The concentration of the dissolved oxygen in the steps one and two were kept at 0 to 3 mg/lit and 3 to 6 mg/lit respectively. In order to make the results of the experiments comparable, a vessel containing a sample of sludge without worms, along to another vessel containing worms, were set up as a criterion under the same set-up conditions, and all the observations were conducted regarding them. Every 24 hours, aeration was stopped for a short time and utilizing a fine mesh, the worms were separated and prepared for entering the next step. The species of the aquatic worms during the days of the experiment were similar, selected from the same initial population which was under the experiment. In all the experiments which were carried out standardized methods were applied, and the obtained results were assessed based on ANOVA analysis and T statistical test in order to investigate the average differences at a reliable level of 95%. The Smirnov-Kolmogorov test was applied to determine the normal distribution of the findings. The effect of water evaporation in aeration was noticed via adding sample volume about 20 percent at the beginning. Selection of 20 percent is based on experiments in this study.

In order to take samples of the deposits to find the intended aquatic warm species and to carry out field tours, a collection of outdoor equipment including the Sampler VN, a GPS, electrical conductivity meter, mercury thermometer and digital thermometers, kit for measuring dissolved oxygen in water, a sieve with one millimeter meshes, and others were utilized for the transportation of samples. In addition to conventional laboratory equipment in water and wastewater laboratories, a portable oxygen-meter was also used to make regular measurements of the dissolved oxygen in the reactor. The most important material of the survey was the aquatic worm, Oligochaeta, from the species of *Lumbirculus variegatus*, which was collected from the wetlands in Kermanshah Province. Also, the waste sludge which was used as a material, was daily provided from the return line of WWTP in Ahvaz. Other chemicals with a high purity were also used on the experiments on sludge [14].

III. Results

The TSS measurement in the incoming and outgoing sludge of the reactors indicated that the average concentration of this parameter in the outgoing sludge from the first-phase reactor was equal to 3428 mg/lit and in the second-phase reactor was equal to 2873 mg/lit. Statistical tests showed that there was no logical difference between the results of the two phases of the experiment.

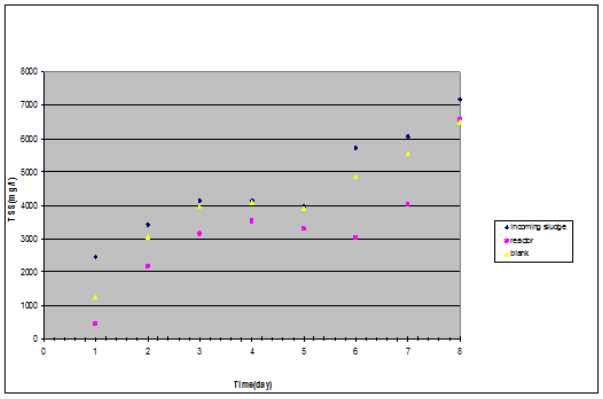

Fig. 1. TSS concentration in reactor and blank –run I.

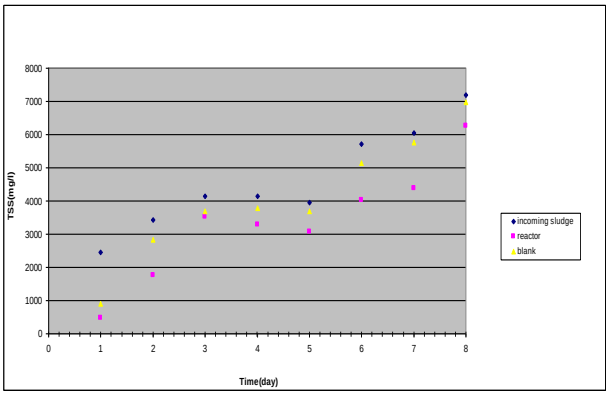

Fig. 2. TSS concentration in reactor and blank - run II.

Investigation of Fig. 1 and Fig. 2 showed that, during the whole days of the two phases of the experiment, the total suspended solids in the outgoing sludge was less than the outgoing sludge. The rates of reduction in the reactors as well as the blank ones were shown on Fig. 3. A comparison of the Figures indicated that the rate of efficiency in the second-phase reactor was equal to 33%, which compared to the 32% of the first-phase reactor was slightly higher. The rate of TSS reduction in reactor and blank in each phase had not logical differences. The ates of TSS reduction in the blank reactors in the two phases were 16% and 12% respectively. Furthermore, statistical analyses showed that there was no sensible difference between the rate of reduction in the reactors during phases one and two. In another word, oxygen concentration had no effects on TSS reduction by aquatic worms. The conductance of Smirinove-Kolmogorov normal distribution test on the suspended solids in the sludge and the

dissolved oxygen showed that the data had followed a normal distribution. The T test was applied to investigate the meaningfulness of the average differences in the data regarding the reactor and the blank in the two phases of the experiment, and the results showed to have a reliable level of 95%. It was also specified that, since the P value was equal to or less than 5%, there would be a meaningful difference between the average concentrations of the suspended solids in sludge of the reactor and the blank one at the error level of 5% (the reliable level of 95%). In other words, according to the similar medium condition of the reactor and the blank one, this meaningful difference in the concentrations of the output of the reactor and the blank might be because of presence and performance of the worms in reducing the concentration of this parameter [14].

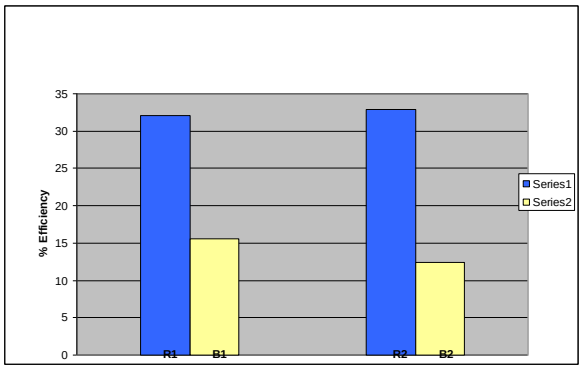

Fig. 3. Efficiency of reactor and blank in run I and II.

IV. Discussion

In the present study, the rate of reduction of suspended solids in the sludge in the first-phase and the second phase reactors were found to be 30% and 33% respectively, and in the blank reactors were 16% and 12% respectively. In the reactor containing the aquatic worms *Lumbriculus variegatus*, which were experimented by Hendrickx and his colleagues, the rate of TSS reduction in the sludge of the reactor containing worms was three times greater than the rate in the reactor without worms. In the present study, this rate was calculated to be 1.9 to 2.7. In Hendrickx's and his colleagues' study, the average rate of TSS reduction in the reactor with worms was 49%, which may be due to the difference in the methods of experimentation of the two researches [14]. In another research conducted without developed media in Netherlands, a less reduction of sludge (10%-50%) than that of Hendrickx's was observed (similar to that of the present research), and it showed that efficiency was depended upon the conditions of production, like motionlessness of the worms.

In another survey which was carried out in China on the reduction of waste using a system which utilized a combination of Protozoa and Metazoa, the rate of reduction (in MLSS) was from 45% to 58%, compared to that of the blank reactor. In this survey, the DO concentration was considered 1-4 mg/lit, and the hydraulic retention time of wastewater was 6-13 hours. It had to be pointed out that in the above-mentioned research, the reduction in the biomass of the aerobic system of the wastewater treatment plant was the focus of observation and no survey was carried out on the outgoing sludge of the system [19]. In another study which was carried out in China on the aquatic worm species of Tubificide, the average TSS reduction in the sludge was 48%, and the DO concentration was about 2 mg/lit, and even more.

A comparison of the 48% reduction of the above-mentioned research with that of the present research (33%) shows that the aquatic worm Tubificide has a better performance than the species of *Lumbriculus variegatus*. Of course, the method used in the experiment performed in China differs from that used in the present research in that in China they alternately used two reactors containing worms, so the difference in the results of TSS reduction may be due to both the species of the aquatic worms and the method used in the experiment.

In addition, another research was conducted abut an aerobic reactor on the activated sludge containing worm species of *Lumbriculus variegatus* in Netheland, which showed a reduction of up to 30% compared to that of its blank reactor. The result of this research (30%) was almost equal to that (33%) of the present research in which the worm species and the treatment method were applied in the process (activated sludge) [12].

Another survey was carried out by Liu and his team in China. In this research, a reactor containing worm species of Tubificide was used to reduce sludge, and an efficiency of 46.4% was reached. The SRT (Sell Retention Time) of this research was 30 days, the hydraulic retention time was estimated to be 15.4 hours, and the DO concentration was measured to be 0.5-3 mg/lit [20].

Another research was carried out in China to make a comparison between the efficiency of a membrane biological reactor (MBR) and that of a conventional activated sludge (CAS) in the reduction of sludge by the aquatic worm species, Oligochaeta, at pilot-plan scale in a period of 345 days. The results showed that the performance of the worms in the MBR system did not lead to considerable reduction in the sludge and its settling characteristics. Whereas in the CAS system, the development of the worms drastically reduced the sludge and improved the characteristics of the sludge. The average of sludge production was much less than that of processes without worms. The results of the above research justified the performance of the worms in reducing the conventional activated sludge, and due to its similarity with the treatment method which was used in Ahvaz wastewater plant, that was a conventional activated sludge, the results of the present research were justified with regard to the effective performance of worms in the reduction of sludge [10].

In another research performed in China, the reduction of sludge by four species of Microfauna was identified and compared. The daily rate of reduction in the species of Microfauna was from 0.1 to 0.54 mg sludge/mg worms, which was different from one another in terms of the order or body size of the worm.

In this research, the average reduction by the species *Lumbriculus variegatus* was found to be about 0.45 mg of sludge per one mg of the worm per a day, which was quite similar to the results of the above-mentioned research. Another important finding was through the research which was conducted on the four species of Microfauna. Among these four species, those with smaller body size, because of

the higher energy consumption, reduced sludge to a greater deal. Also, the rate of reduction by Microfauna depended on the speed of the sludge reduction and the number of organisms in the reactor [9].

The quantitative result of this research, regarding the TSS sludge reduction by worm species *Lumbriculus variegatus*, indicated that the results of this research were in agreement with those of other researches; however, unlike some researches that ratified the relationship between the DO concentration and the rate of TSS reduction, in this research no logical relationship was found between the two parameters [14].

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