DEVELOPMENT OF TECHNOLOGY FOR DIFFERENT NATURE DREDGES CONCENTRATION AND SEPARATION FROM LIQUID WASTE

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ABSTRACT

The treatment of different origin liquid wastes (LW) is nearly always concerned with the problems of insoluble suspended particles (dredges) concentration and removal. Diverse traditional methods of the filtering concentration are efficient enough for solving the problems, if the initial concentration of dredges in liquid solutions is not more than 1 g/l. There are many reasons for the LW clarification, but as a rule, the main one is the further waste handling. In this case, it means either the waste neutralization or the possible purposeful use of separated or extracted components.

For the greater part, the liquid wastes are wastewater. Suspensions and pulps are the most problematic objects in the wastewater treatment. As a rule, the dispersible composition of dredges has a wide span. It considerably complicates the matching of clarification methods and the designing of technological equipment. The problem becomes moreover complicated, if there is the need for removing a considerable quantity of dredges with the insoluble particles of sizes from 1 μm up to 1000 μm and of a complex chemical composition and morphology.

Within the bounds of the experimental-technological and experimental-design works being currently carried out, it is supposed to develop a universal approach to the treatment of liquid wastes (mainly wastewater) containing dredges in considerable quantities. After separation, the sludge (silt, pulp, residue, etc.) can be utilized or conditioned with the following either neutralization or storage or burial. The purified water can be recycled or headed into a general sewage disposal plant.

This paper reports about exploratory studies, and therefore, it takes up only some aspects of the liquid wastes treatment technology being currently in the making.

INTRODUCTION

In practice of the liquid radioactive waste (LRW) storing and subsequent processing, the problem of concentration and removal of dredges is the most topical, because LRW can contaminate dredges with radionuclides. The Moscow SIA “Radon” is an enterprise, which concerns with the collection, the conditioning (processing) and the storing of diverse forms of the radioactive waste arising from the non-nuclear application. Such wastes come from different industrial enterprises, scientific research centers and medical institutions of the Central Region of Russia. Fair quantities of the liquid radioactive waste of different chemical and radiochemical compositions come for processing and storing to the Moscow SIA “Radon” site. Therefore, the sedimentation and accumulation of dredges permanently occurs in LRW storing tanks. Besides, there is a system for collecting, monitoring and purifying the surface run-off (rain, snow, etc.) from the site and drainage effluents from near-surface repositories of radioactive waste. The gradual silting-up of the system with silt sediments, sludge, etc (formation of dredges) can considerably decrease the efficiency of the liquid waste purification.

For solving the problem of the dredges (sludge, pulp, silt, etc.) treatment, experts of the Moscow SIA "Radon" have recently started developing a technology for them removal, concentration and separation (dewatering).

In the course of the technology development, laboratory and field trials of worked out technological units were conducted. The first object of the trials was oil-slime from one of the Moscow petroleum refineries. Many producers dealing with the oils production or processing have water tailings (i.e. wastewater) with a high content of oil products, sediments and soluble organic or inorganic substances. To begin with, considerable quantities of admixtures, especially insoluble, do not allow directing such wastewater without a preliminary treatment towards general sewage disposal plants. At the same time, an economically acceptable treatment of such wastewater is difficult, because most traditional technologies including the filtration through sand filters, the ion exchange, the sorption, and other methods turn out to be ineffective at contents of admixtures more than $10\%_{wt.}$ (or more than 100 g/l). On the other hand, such wastewater accumulates in storage ponds and becomes a source of the dredges, which should be eliminated in time.

Another object of trials was wastewater containing considerable quantities of clay-silt dredges.

Results of the experimental works fulfilled to the current moment are reported hereafter.

Treatment of Liquid Wastes Containing Dredges

A general strategy in developing a technology for the treatment of liquid wastes containing considerable quantities of insoluble substances requires the elaboration of a certain concept. Figure 1 represents a functional chart of such liquid wastes treatment.

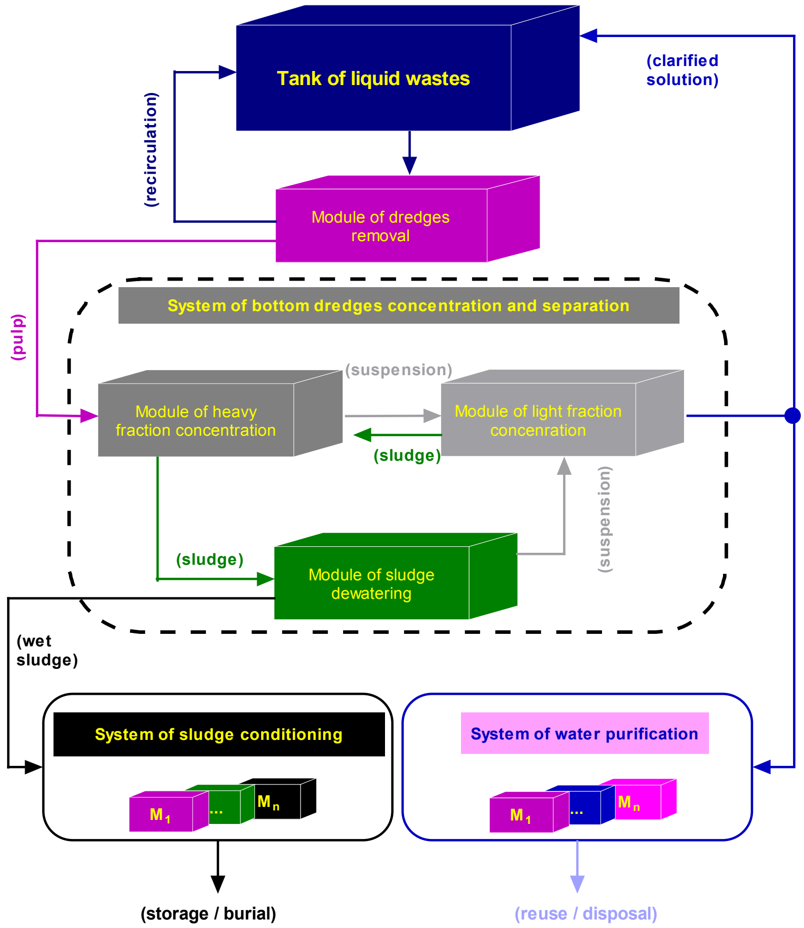

Fig. 1. Treatment of liquid wastes containing dredges.
M_1 – M_n – diverse modules or installations.

The functional chart should be put in the basis of the treatment of liquid wastes containing dredges of any origin. As far as the concept is under development, only the content of the functional chart will be explained hereafter.

The functional chart includes several systems consisting of modules. Each separate module is a completely self-contained installation, which the functionality is based on one or few methods. Such installation includes the following: one or few main apparatus; auxiliary apparatus providing the regular performance of main apparatus; diverse equipment; a common tray; a support frame for fixing the equipment and for loading-unloading and transportation of the module. Each system consists of one or few modules intended for a certain purpose in the system. In the whole, such way of LW treatment allows flexibly approaching to solving the problem of dredges treatment in particular cases.

Currently, the systems of sludge conditioning and water purification are rather worked out and being applied at the Moscow SIA “Radon”. Therefore, the main aim of studies is development of a module of dredges removal and a system of bottom dredges concentration and separation.

The paper represents some results of the dredges concentration and separation technology development. According to the technology, the primary concentration of dredges is to be conducted in the module of heavy fraction concentration consisting of a riddling unit and a battery of thickening hydrocyclones. According to the research, the module of riddling and hydrocycloning allows effectively removing coarse fractions of dredges including particles of sizes more than 1000 µm. At that, a concentration factor of such dredges can make not less than 2. On the other part, the module of heavy fraction concentration allows coordinating the stage of the dredges removal and the stage of the sludge dewatering.

Stages of the sludge dewatering and the light fraction concentration are to be carried out in a filtration-separation module. The essence of the sludge dewatering and dredges concentration is in a method of reverse filtration or in other words a filtration under vacuum through a rotating filtering surface of a porous material. The main advantages of the reverse filtration through the rotating filtering surface of a porous material in comparison to the direct forcing filtration are that the energy consumption for the vacuum creation (up to ΔP = -0,99 bar) is low and the rotating of the filtering surface allows organizing a mechanical removal of dredges from the surface. On the other hand, due to control of the filtering surface rotation frequency, it is likely possible to create such conditions when a near surface layer of dredges never or slightly forms on the filtering surface.

Concentration of Oil-Slime and Clay-Silt Suspension

The most experiments were ones with the wastewater containing oil-slime.

A two-stage treatment of such wastewater is offered. The first stage - the filtration through some tissue or porous materials (i.e. microfiltration membranes made of porous stainless steel - PSS) is intended to separate the bulk of dredges both of organic and of inorganic origin. The second stage is the ultrafiltration of permeate from the first stage.

The original wastewater containing the oil-slime is a black-colored oily liquid with various solid amorphous admixtures. Average density of such wastewater was about 980 kg/m^3.

The slime after separation of free water looks like a black-colored wet and oozy paste with an obnoxious smell of organic substances (oil products). Specific weight of the slime was about 950 kg/m^3.

Approximate composition of the slime obtained after filtration through the PSS membrane (sizes of pores - about 50 µm) in laboratory trials (Fig.2) is as follows:

- free water contents in wastewater – 55% (wt.)
- crystal water contents in the slime – 10% (wt.)
- organic fraction contents in the slime - 17% (wt)
- mineral fraction contents in the slime – 18% (wt.).

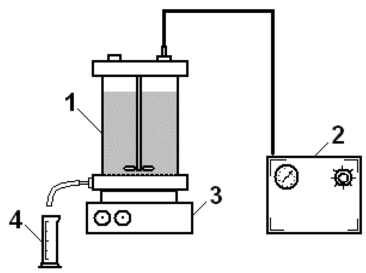

Fig. 2. Microfiltration static stand:
1 – filtration cell; 2 – air compressor; 3 – magnetic stirrer; 4 - graduate.

Chemical composition of permeate after the additional one-pass filtration through a static ultrafiltration stand (Fig.3) is given in Table1.

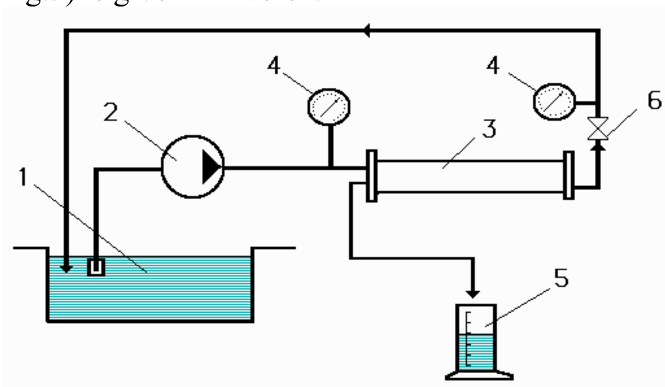

Fig. 3. Hydraulic scheme of pilot ultrafiltration stand:
1 – tank of treated permeate; 2 – centrifugal pump; 3 – roll type ultrafiltration apparatus (length - 1 m, diameter - 0,1 m); 4 - manometers; 5 - graduate; 6 - throttle flap.

It was experimentally established that productivity of the pilot ultrafiltration stand is rather high (up to 380 l/h at 0,2 MPa). The permeate after ultrafiltration was a colorless transparent aqueous solution with a slight smell of oil products.

Comparison of the chemical analysis data with recommended maximum allowable concentration (MAC) of pointed components in the permeate after ultrafiltration [1-3] have shown the excess of concentration only for ammonia (MAC c. 2,5 mg/l) and phosphates (MAC c. 6 mg/l). At the same time, if a sewage disposal plant includes biological treatment of wastewater works, then the mentioned substances will be necessary for the microflora feeding. Hence, they cannot be considered as toxicants in such wastewater (for instance, quantity of phosphorous required to microflora of sewage disposal plants is determined as 1 part of phosphorous per 90-150 parts of biochemical oxygen demand of wastewater [2]).

Table I. Chemical composition of permeate after ultrafiltration.

Chemical composition							
Index	**Dry remainer**, g/l	**pH**	**COD**, mgO_2/l	**SAM**, mg/l	**Oil products**, mg/l	**Hardness**, mg-eq/l	**Na^+**, mg/l
Value	1,515	7,06	167	2,2	22,5	11,7	277
Index	**K^+**, mg/l	**NH_4^+**, mg/l	**Ca^{2+}**, mg/l	**Mg^{2+}**, mg/l	**$Fe_{total.}$**, mg/l	**Cl^-**, mg/l	**NO_3^-**, mg/l
Value	21,4	65	153,5	49	slight	564	0,9
Index	**SO_4^{2-}**, mg/l	**HCO_3^-**, mg/l	**CO_3^{2-}**, mg/l	**PO_4^{3-}**, mg/l	**OH^-**, mg/l	**Cr,** mg/l	**Zn,** mg/l
Value	124	1047	n/f	67	n/f	0,001	0,07
Index	**Mn,** mg/l	**Cd,** mg/l	**Cu,** mg/l	**Hg,** mg/l	**Pb,** mg/l	**Ni,** mg/l	
Value	0,22	0,00039	0,079	0,00043	0,034	0,074	

n/f – not found; COD – chemical oxygen demand; SAM – surface-active material.

Trials of the pilot ultrafiltration installation showed that the main problem of clarification of the wastewater contaminated with a considerable quantity of oil products is in the separation of slime from the aqueous fraction. As an apparatus for the separation of slime from wastewater, it is supposed to use a vacuum drum-type filter, which is widely applied in the atomic industry [4].

A small laboratory drum-type vacuum filter of original design was made to study the slime separation from wastewater (Fig.4).

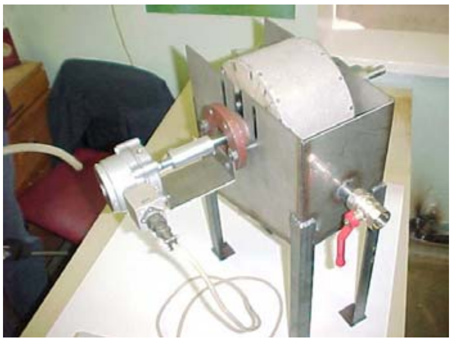

Fig. 4. Overview of laboratory drum-type vacuum filter

The main element of the laboratory drum-type vacuum filter is a cylinder drum of a special design made of polyamide. Diameter of the drum is 200 mm, width - 110 mm. Outer surface of the drum is covered with a sheet porous stainless steel (PSS). At one side, a hollow shaft of the drum is plugged and connected to an electric motor by reducer with a muff. On the other side, the hollow shaft is connected to a vacuum system by means of a rubber gasket. A medical aspirator connected to the hollow shaft through a receiver (a buffer tank) creates the vacuum in the laboratory stand and is a collector of permeate. Frequency of the drum rotation (from zero up to few rpm) can be changed by a variable-frequency electric drive. The slime accumulated on PSS surface is cut with a plastic scraper and directed along a gutter into a collector. Total area of the filtering surface is equal to 628 cm^2.

The overview of the laboratory stand during the field trials is in Fig.5. Average frequency of the drum rotation during the trials was about 2 rpm. Ratio of slime and permeate (aqueous fraction) was approximately 1:1 (by volume).

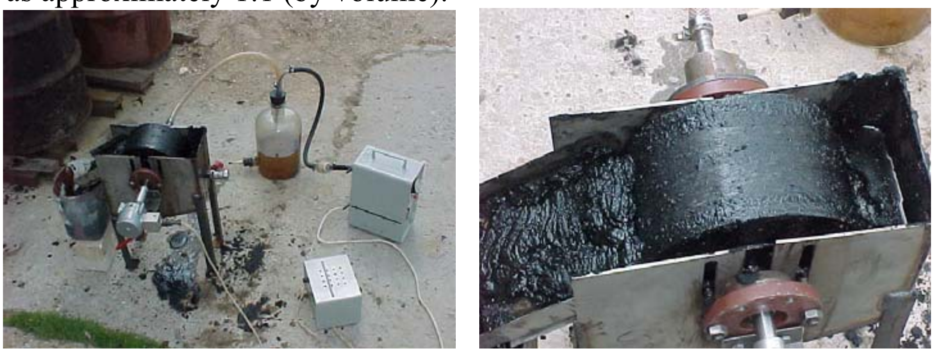

Fig. 5. Overview of laboratory stand during the field trials

Results of the trials showed that an average productivity of the laboratory drum-type vacuum filter was about 0,6 l/h (or 0,23 $m^3/m^2 \cdot day$) at vacuum -0,08 MPa. Specific productivity of the PSS membrane in the microfiltration static stand (Fig.2) was only 0,043 $m^3/m^2 \cdot day$ at pressure 0,2 MPa. Therefore, the rotating drum-type vacuum filter allows intensifying the filtration almost in 5 times. Increase of the filtration surface area levels the filtration productivity up. Application of a rotating disk-type vacuum filter design increases the filtration surface area. To check the functionality of such design, a disk-type filtering element was made and tested (Fig.6).

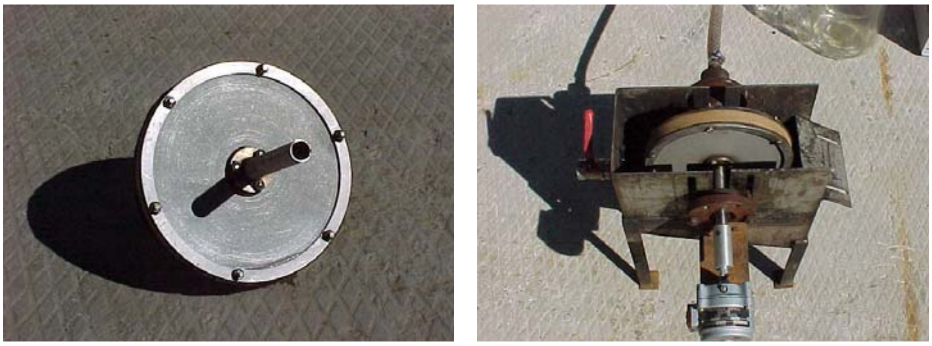

Fig.6. Overview of laboratory disk-type vacuum filter

In the given case, disk-type filtering elements can be assembled in cassettes (similar to a pressure filter) and thus, it will considerably reduce dimension of the apparatus. Such principle is used in multi-disk membrane centrifuges of the American firm SpinTek and the Russian firm "ULTRAM".

The filtration area of the disk-type filtering element is 535 cm^2. Experiments conducted with the disk-type vacuum filter (Fig.7) showed that the greater efficiency of such filtering element in comparison with the drum-type filtering one. It was also noted that increase of temperature of treated wastewater and increase of the rotation frequency of the filtering element effect positively on the filtration productivity (Fig.7).

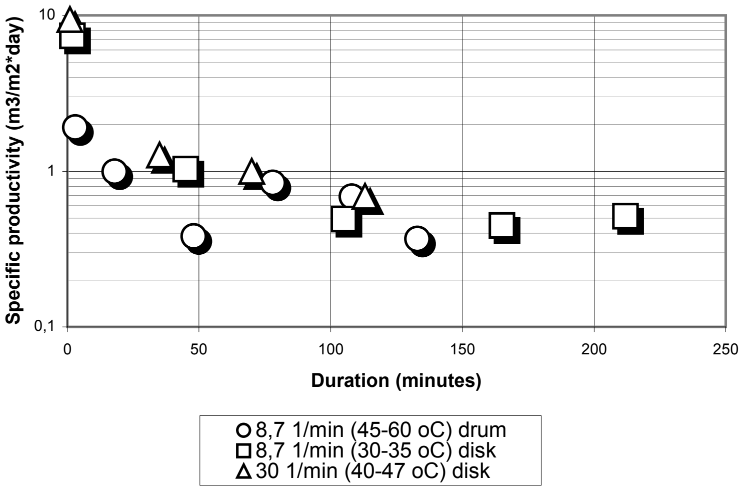

Fig.7. Specific productivity of the laboratory drum (disk)-type vacuum filter by filtrate (permeate) at different rotation frequencies and temperature of real wastewater.

The disk-type filtering element was also used in experiments with clay-silt suspensions. The clay-silt suspensions were from one of natural ponds in the Moscow region.

The average concentration of freely suspended (not settling during 15 minutes) clay-silt particles in suspensions of all the experiments was about 20 g/l. The vacuum in the disk-type filtering element was not less than –0,03 MPa. The average rotation frequency in these experiments was about 60 min^{-1}. Temperature of the suspension did not exceed 25 °C.

The average productivity of the disk-type filtering element by permeate made 1,65 l/h (or 0,73 $m^3/(m^2{\cdot}h)$). In the experiments, the clay-silt dredges have being concentrated directly in the working shell of the laboratory disk-type vacuum filter (Fig.6). At that, a layer of the dredge forming on the surface of the disk-type filtering element was not mechanically taken off during the filtration. The layer of the dredge was every hour taken off the surface by means of turning off the vacuum and flushing the filtering element with a squirt of suspension in 5 – 6 min. After each 6 – 7 hours of the filtration the disk-type filtering element cleaned of visible dredges was immersed into 0,3% H_2O_2 solution for 10 – 12 hours. Such treatments allowed almost completely regenerating the average productivity by permeate of the filtering elements.

CONCLUSIONS

The trials showed that the productivity of the vacuum filter by purified water solution (permeate) decreased in time. Probably, it was due to the clogging of surface pores in the PSS membrane with solid particles and blocking of volume pores with organic substances. Mechanical cleaning of the PSS membrane did not regenerate it. It was experimentally found out that the productivity of the filtering element can be regenerated with hot water (t = 95 °C) treatment during 1 hour. However, such method of treatment is not convenient in practice. Another method of PSS membrane surface treatment consists in pumping of 0,3% H_2O_2 solution heated up to 30 – 35 °C through the membrane.

The results obtained in the trials allow asserting that the specific productivity of the disk-type filtering element made of sheet PSS membrane is quite acceptable at concentration and separation of the slime, because the rating of the specific productivity of most membranes makes 0,5 - 5 $m^3/m^2 \cdot$day [5].

Recently, a pilot installation "Augean" has been assembled. Its theoretical productivity by initial wastewater is to be to 50 l/h at contents of free water c. 50%. The pilot installation "Augean" consists of the disk-type vacuum filter equipped with five filtering elements. A total of filtering surface area is 2 m^2. A program of the installation trials on dredges from LRW storing tanks is being prepared. The aim of the program is lifespan tests of filtering elements and improvement of them regeneration or replacement methods.

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