OPPORTUNITIES FOR WATER TREATMENT SLUDGE RE-USE

MOŽNOSTI VYUŽITÍ ODPADNÍCH VODÁRENSKÝCH KALŮ

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Abstract

This paper deals with the sludge that is produced within the treatment of water and production of drinking water. When alumina and iron coagulants are used for coagulation and clarification of surface water, mainly alumina and iron sludge are produced. This paper describes possible alumina recovery in the water treatment procedure and re-use of sludge for treatment of municipal wastewater. The sludge can be also used for production of cement. All those actions decrease the quantity of wastes and contribute to environmental protection. The waste sludge can be also used as secondary raw materials.

Abstrakt

Tento příspěvek se zabývá kaly, které vznikají v procesu úpravy vody na vodu pitnou. Jde zejména o hlinité a železité vodárenské kaly vzniklé při úpravě povrchových vod koagulací a čiřením za použití železitých a hlinitých koagulantů. Jsou uváděny možnosti využití hliníku zpět v procesu úpravy vody, využití kalů při čištění městských odpadních vod. Využití kalů při výrobě cementu. Důvodem pro takové postupy je snižování objemu odpadu, a tím ochrana životního prostředí. Dále pak využití odpadních kalů jako druhotné suroviny.

Key words: wastewater treatment sludge, alumina recovery, aluminic coagulant, flotation

1 INTRODUCTION

Much water treatment sludge ("water treatment sludge") is produced in the production of service water and drinking water. It is impossible to prevent the production of water treatment sludge. The water treatment sludge is liquid and solid and is regarded as a waste. Consequently, the water treatment sludge must be handled in accordance with regulations in forces. The quantity of the water treatment sludge is rather high. According to the Czech Statistics Office, the Czech Republic produced 34,494 tons of the water treatment sludge in 2006 (the quantity is expressed in dry mass). The water treatment sludge is placed mostly in landfills. In some countries, for instance in the Netherlands, about 25 per cent of the produced water treatment sludge is re-used.

It is still an issue to choose a disposal or liquidation method for the water treatment sludge that would be reasonable in terms of technology and economy. According to environment protection regulations it is required to minimise the quantity of wastes produced. If possible, the wastes should be re-used or processed as secondary raw materials as much as possible. If this is not possible, the solid wastes should be put back in the environment where the space occupied should be as little as possible and minimum costs should be incurred [1].

The composition and properties of the water treatment sludge depends typically on the quality of treated water as well as on types and doses of chemicals used during the water treatment. Depending on the quality of the treated water, the water treatment sludge contains suspensions of inorganic and organic substances. Typically hydrated alumina oxides and iron oxides are present (this depends on coagulants used for the treatment) [2].

Most of the water treatment sludge is made of alumina sludge. Efforts exist to recover alumina from the water treatment sludge during the water treatment or to use the alumina sludge for wastewater treatment or as a secondary raw material. The iron sludge can be also used for wastewater treatment. It is also possible to use the water treatment sludge in production of cements. Investigations are being carried out into the use of the water treatment sludge in agriculture and forestry.

Production and composition of the water treatment sludge

The term "water treatment sludge" covers all wastes produced during treatment of water in a water processing plant. It is rather difficult to define the water treatment sludge in more detail as the water treatment sludge comprises both the sludge (this means, the real waste) and the wastewater.

Properties of the water treatment sludge depend typically on the quality of raw water and treatment method. On one hand, if ground water with a rather stable quality is treated, the quantity and quality of the water treatment sludge fluctuate very little. On the other hand, the treatment of surface water results sometimes in rather considerable changes in the quality of raw water. Typically, organic and mineral suspensions occur in the water treatment sludge. Due to the changes in the quality, it is necessary to change the dosing of chemicals. All this results in qualitative and quantitative changes in the composition of the water treatment sludge. Contamination of the surface water is caused often by clay minerals, sandy and loamy particles as well as organic remains of plants and animals.

From the physical point of view, the water treatment sludge is a polydisperse suspension with a wide range of rough disperse or even colloidal particles. Individual particles of the solid phase that are kept in the liquid phase in a dispersed phase by charges of the particles can create secondary agglomerations – flocs. When the dispersed particles are agglomerated, the used chemicals create frequently a considerable part of the sludge [3].

Depending on the place of origin, the water treatment sludge can be divided as follows [4]:

1. Rough trash caught in trash-racks. The character is really various. This sludge contains little water only. The quantity of this trash is very low.
2. Floc suspensions of iron and alumina oxides from thickening sections in settlement tanks and clarifiers, incl. the caught trash. This sludge contains much water.
3. Filter washing sludge (the washing wastewater). This sludge is flocculent with small flocs. The settling velocity is low.
4. The sludge from removal of iron and manganese from ground water. Since lime is fed often and the sludge is easy to thicken thanks to high dehydrating of iron oxides, this sludge is easily processable. The quantity of this sludge is low and disposal is rather simple.
5. Decarbonization sludge. Sediments are more compact than flocculent sludge. The decarbonisation sludge is sometimes used as a fertilizer in the agriculture and does not represent a major issue.
6. Polymeric flocculant clarification sludge. This sludge contains typically suspended and colloidal particles contained in the treated water. Since fed quantities are rather low, the contents of the polymeric flocculants is low too.
7. Other water treatment sludge. This is the sludge from slow sand filters, sluicing filter sludge and activated carbon washing sludge.
8. Wastes produced in preparation of chemicals for the wastewater treatment.
9. Saline water from ion exchanger recovery and membrane processes.

When the surface raw water is treated mechanically, this means by sedimentation or simple filtering, the sludge is taken from the settling tank bottom or is taken by the washing water from the filter recovery. The sludge dry mass contains mainly mineral substances, sandy and loamy particles and some small quantities of substances of an organic origin, such as humine substances, remains of organisms, or algae. When the suspension is separated in one level, almost all dry mass (depending on an efficiency of a separating unit) is removed from the washing or spraying water in the recovery of the filtering medium. Typical concentration of the dry mass in the sludge water produced in the washing of grainy filtering materials is 0.02% on average. If acid clarification filters are washed, the dry weight concentration goes up slightly to 0.025 - 0.03%. The washing of alkali clarification filters results in 0.1% of dry mass.

The quantity of sludge water ranges from 1 to 5 per cent of the total untreated quantity [5]. In the first 6 minutes, the dry weight concentration in the washing water is 3 to 5 times higher than an average. Contamination of the washing water in the remaining washing time is very little.

In two level processes, the first level of separation (this means, the settling tanks or clarifies) removes 70 to 90 per cent of suspensions. The remaining quantity is removed when washing the filters. Concentration of the sludge leaving sludge sections of the separators depend on the technology and discharge methods. The construction of the plant plays a role too. An average concentration of the dry weight in the discharged acid clarification sludge and alkaline clarification sludge is 1.5 to 2.5 and 2 - 4 per cent per year, respectively.

The most important group of sludge comprises the sludge produced in the acid clarification of the surface water. This group of the sludge makes up the biggest quantity of the water treatment sludge. This sludge is considerably hydrated, very difficult to dewater and dry up [6].

Typical coagulants in the water treatment include aluminium salts and iron salts. The most popular is aluminium sulphate and aluminium sulphate modifications or combinations, such as chlorine aluminium sulphate. Ironic sulphate is the most frequently used coagulant from among iron salts. Therefore, the main component of the water treatment sludge is alumina and iron hydroxides produced in hydrolysis during the coagulation.

Tab. 1 shows the average composition of the water treatment sludge (Benešová, [6]).

Tab. 1 Typical composition of the alumina and iron sludge (average values)

Indicator	Alumina sludge	Iron sludge
pH	7.6	7.97
Total dry mass %	5.46	3.15
Ignition loss%	31.6	28.8
R_20_3 %	31.2	28.9
Al_2O_3 %	28.5	2.76
Al %	15.07	-
Fe_2O_3 %	2.7	27.6
Fe %	1.88	19.5
Ca %	6.78	5.66
Mg %	1.56	1.32
Mn %	0.19	0.10
N total %	0.006	0.008
P total %	0.002	0.003

Depending on the quality of the treated water, wastes are also produced in the membrane and ionex washing and/or recovery.

The composition and quantity of the sludge can by calculated by a formula suggested by Žáček [7] where following relations apply to the composition of the sludge produced in clarification of the surface water:

$$p_k = \frac{100\,k\,D}{q_{su} + k\,D + (q_s - q_u)} \qquad [\%]$$

$$p_o = \frac{100\,(q_s - q_u)}{q_{su} + k\,D + (q_s - q_u)}, \qquad [\%]$$

where p_k, p_o stand for the concentration of Fe, Al or organic substances in the sludge (weight %), D – is a coagulant dose ($mg.l^{-1}$), k is a coagulant-to-oxide conversion coefficient, q_{su} is the contents of suspensions in the treated water ($mg.l^{-1}$); q_s, q_u are weight concentrations of organic substances in the raw water and treated water ($mg.l^{-1}$) (if the concentration of organic substances is expressed as COD_{Mn}, it is also essential to take into consideration the specific COD $CHSK_{Mn}$ for caught substances).

Following calculation formulae apply to the composition of the sludge produced in manganese and iron removal and decarbonisation:

$$p_{Fe} = \frac{100\,q_{Fe}}{q_{su} + 1{,}43 q_{Fe} + 1{,}58 q_{Mn} + m_{CaCO_3}} \qquad [\%]$$

$$p_{Mn} = \frac{100\,q_{Mn}}{q_{su} + 1{,}43 q_{Fe} + 1{,}58 q_{Mn} + m_{CaCO_3}}, \qquad [\%]$$

where p_{Fe}, p_{Mn} are the contents of Fe and Mn in the sludge (weight %), q_{Fe}, $q_{Mn,}$ are weight concentrations of Fe and Mn in the water (mg l^{-1}), q_{su} is the concentration of particles suspended in the water (mg l^{-1}) and m_{CaCO_3} is the weight of calcium carbonate deposited from 1 liter of water.

Water treatment sludge treatment and disposal technologies

The water treatment sludge disposal methods are the following: the sludge can be discharged directly into water courses or deposited freely without any treatment or fed to wastewater treatment plants.

Now it is impossible to discharge the sludge or sludge water directly into rivers. When discharging the wastewater, it is necessary to comply with the Czech Republic Government Decree No. 229/2007 Coll. that sets indicators for permitted water pollution.

It is possible to place the sludge in free spaces such as abandoned quarries, mines, gravel pits, sand quarries or artificial lakes. Of course, environment protection regulations and current legislative must be followed. In rare cases only, the suitable space is available close to the water processing plant.

The placing of the water treatment sludge into free spaces can be regarded as an emergency solution that does not solve the issue forever, but moves the issue until the time when the storage space is used up.

There is one major disadvantage in the mentioned solutions - the sludge under water is difficult to thicken. Under the water level, the sludge thickening reaches 6, maximum 8 per cent. This is the case of alumina water treatment sludge. The low thickening results in the sludge storage space to be filled up too quickly – this was the case of the water processing plant in Želivka.

A possibility for disposing the water processing sludge is to feed the sludge into a municipal wastewater plant where the sludge will be treated together with the municipal wastewater.

The water processing plant is required to be close to a sewage system. The wastewater treatment plant must have such capacity to be able to treat the sludge diluted reasonably with a view to a biological nature of the municipal wastewater treatment.

The co-operation between the wastewater treatment plant and water processing plant is a good choice if the filter washing wastewater is discharged at night when the wastewater treatment plant is not loaded so much. In case of a tidal discharge, balancing tanks can be used to balance flow rate. It is necessary to assess influence of the water treatment sludge on functions of individual treatment units and on the quality of digested sludge.

If the conditions are favourable, this is a preferred method for the wastewater sludge disposal.

The basic technology step in the processing of the water treatment sludge is a decrease in water contents. Without this step, it would be difficult and considerably uneconomical to handle and treat the sludge. Both the filtering washing water and sedimentation/clarification sludge need to be sedimented or thickened.

This is typically carried out in sludge drying beds or lagoons when natural dewatering processes take place for a rather long time. The dry weight of the sludge can be as much as 40% and final disposal is possible.

As far as fully mechanised dewatering units for the treatment of the water treatment sludge are concerned, introduction of standard centrifuges and filter presses has started recently.

The fully mechanised dewatering units can be divided as follows:

- filter press filtering (cage presses or pressure band filters)
- vacuum filtering
- centrifugal separation

In order to improve filtering properties of the water treatment sludge, most sludge needs to be processed. Typical chemical processing includes a feeding of lime or polymeric flocculants. Physical methods include freezing, heating up or ultrasonic treatment [8]. Dry dewatered sludge is placed in landfills. Some sludge is used for reclamation. New reuse opportunities are being investigated.

Alumina sludge recovery

A possible method for disposal of the water treatment sludge is the alumina sludge recovery. This is regarded as the future method for the sludge handling. The term “recovery" occurs in the Czech literature [9] as well as in translations of foreign works. In other sources, “regeneration” is mentioned [10]. The principle is to recover the coagulant from the water treatment sludge and to re-use the sludge in the water processing. Typically, the sludge alumina is re-transformed to form the aluminium sulphate.

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The recovery using sulphuric acid is simple and cheap, but the alumina recovery efficiency is 40 - 60% only. A disadvantage is that the contamination moves partly to the coagulant. With pH being between 3 and 3.5, it is possible to reach the required quality of the recovered coagulant. Effects of the recovery water treatment is same or better than if a purely commercial aluminium sulphate is used [11].

After the recovery, the sludge is dewatered in vacuum presses. If the band press resisted pH being 2.5, it would be better to use the band presses for the dewatering. Therefore, a decision has been made to carry out semi-trial or prototype tests.

The recovery by Fulton [12] dewaters the sludge and recovers the alumina. The alumina is recovered after acidification of the sludge by means of sulphuric acid. Then, inert materials (flue ash) are fed to improve the filtering. The treated sludge is dewatered in a filter press. The aluminium sulphate in the filtrate is re-used for the water processing. Lime is fed regularly into the filter press in order to neutralise filter cage.

Once the recovery of an alumina coagulant by means of the sulphuric acid was introduced in the U.S.A. (Tampa, Florida), the profit was about 80,000 USD (for 135,000 m^3 of water treated per day). In some water processing plants in Japan, a 80% recovered coagulant is used, for instance in the water processing plant in Tokyo - Asake where the capacity is 2 million m^3 per day. France uses the regenerated alumina coagulant (60%) in the water treatment plant in Orly where the capacity is 100,000 m^3 [12].

Certain disadvantages of the recovery system are known: the plant is rather big (so simple) and needs to be acid resistant, quantities of remaining acid sludge that failed to react are rather high (this is not the case of the Fulton´s procedure) and, in particular, the final product contains many organic substances. This is probably the reason for the method not being so popular so far.

The original intention of the alumina sludge recovery was to decrease the quantity of the needed coagulant, thus saving costs. The purpose of the current research and operation practice is to reduce the quantity of the water treatment sludge that is regarded waste. It is also important to know whether it is possible to re-use the alumina once the alumina coagulants are less available or the price of the alumina coagulants increases considerably.

Investigations have been carried out in the recovery of the alumina from the water treatment sludge produced in the water processing plant in Podhradí. Attention has been paid to flotation that can separate the sludge from the regenerate [13].

Fresh primary thickened sludge from the water processing plant was used. The dry weight was 1.7%. Concentrated sulphuric acid was fed for the recovery. The reason for using the concentrated acid was to minimise quantities of a reaction mixture. As found out earlier, the concentration of the sulphuric acid does not influence the purity of the regenerate or the quantity of alumina recovered.

The pH for the mentioned composition of the sludge is between 2.5 and 2.7. This results in cca. 80% alumina recovery and the organic substance contamination is acceptable. Within this pH, 37 - 52 per cent of the organic substances became recovered.

The key task was to investigate various methods used for separation of the regenerate solution from the insoluble sludge remains. In laboratories, the efficiency of sedimentation and flotation has been tested for real sludge produced in the water processing plant in Podhradí that uses the technology for a one-level coagulation filtering where the coagulant is the aluminium sulphate.

Flotation has been tested in laboratory flotators in a floto-flocculation cycle with air flotation. Investigations has been made in a mechanical air dispersing flotation as well as in electrolytic flotation. In a flotation chamber, the air saturation system was replaced with electrodes and water electrolysis produced gas bubbles. The sedimentation was evaluated and assessed by means of standard sedimentation tests in settling cones with the height of 2 m.

Tab. 2 provides an overview of qualities of the treated coagulant after recovery

Tab. 2 Qualities of treated coagulants after recovery

Action	dissolved alumina	oxidability	insolubles
	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$
sedimentation	2 240	892	460
mechanical floto-flocculation	2 070	820	720
electrolytic floto-flocculation	1 020	710	650

The tests have proved that the floto-flocculation can be used for separation of the insolubles. Advantages of this method include a simple technology and low investment costs, if compared with the filter presses mentioned in the literature. This is however at expense of a lower efficiency.

An issue might be neutralisation of sludge remains or a method used for treatment of the acid waste.

Another method is mentioned by Melich [9]: dry disintegrated sludge is mixed with concentrated sulphuric acid and is kneaded to produce a plastic reaction mixture. First, the sulphuric acid takes water from organic substances contained in the sludge. The released diluting heat as well as the heat released from exothermic reactions of the sulphuric acid with components of the sludge increase the temperature of the reaction mix up to 160 – 230°C. With this temperature, as much as 100 % Al^{3+} and about 70% of iron and manganese in the sludge become soluble (the quantity of manganese is however typically rather low in the alumina sludge). Most of the organic bound nitrogen becomes ammonia, this means the ammonia sulphate. And the organic bound phosphorus is mineralised to PO_4^{3-} to a certain extent. The coagulant produced by dehydrating of the sludge organic matters has certain sorption ability and rather good docolorizing properties that might be used in some cases.

The high rate of Al^{3+} recovery, low organic contamination of the final product as well as the level of mineralization of the bound nitrogen and bound phosphorus depends on the temperature of the reaction mixture.

The key prerequisite is that the sludge be dry. This is also the only one disadvantage of the method because intensive thickening, storing and drying-up of the sludge is a must.

Production of the recovered alumina coagulant from the dry sludge is, in fact, the production of the aluminium sulphate directly in the processing plant, where raw materials are less pure than those in the industry. The objective is however to reduce the quantity of the sludge produced. This method can be used in situations when standard raw materials are not available.

Using the sludge for wastewater treatment

Re-use of the iron, or alumina, sludge for the treatment of the municipal wastewater seems to be a promising application.

Tab. 3 describes clearly the re-use of the iron sludge in the municipal wastewater treatment [14].

Tab. 3 Using the iron sludge for wastewater treatment

Application	**Effects**
Discharge into a sewage system	Binding of sulphides with the aim to minimise smell and corrosion and to remove phosphates by adsorption.
Feeding into a sand catcher or settling	Removal of phosphates by adsorption. Binding of sulphides.
Feeding into an activation tank.	Improving the phosphate removal and settling of the sludge.
Feeding in an after-precipitation phase.	Savings of chemicals needed for phosphate removal.
Feeding into sludge digestion tanks.	Binding of sulphides. Digestion stabilisation.
Feeding into the dewatered sludge.	Improved dewatering.

The iron sludge can be used as a matter that binds the sulphides in wastewater treatment [6]. The purpose is to prevent corrosion of concrete sewers, to minimise smell during cleaning of wastewater and to bind sulphides. All this prevents sulphanes from being produced in bio-gas during the sludge digestion.

It follows from a survey carried out among Hamburg waterworks [15] that the sludge containing the iron hydroxides that was discharged into sewers settled down with the same speed or slower than other substances contained in the wastewater. Therefore, there is not a danger that sediments will be created in the sewers. It follows from the test of sulphide elimination in wastewater in the sewers that the continuous feeding of the iron sludge contributes to elimination of the sulphides. An advantage of the continuous iron feed consists in more permanent effects.

Another possibility is to dissolve the iron sludge in a strong acid. Either a ferric chloride solution or a ferric sulphate solution will be produced. The solution contains dispersed components such as organic substances or inorganic suspension. The resulting iron solution can be used as a agent for removal of phosphates in municipal wastewater treatment. Experiments indicate that the efficiency of recovered ferric chloride is the same as that of the commercial ferric chloride.

The best way for re-use of the iron water treatment sludge is suggested by Thole [16] who proposes the iron sludge to be used as an alternative for precipitation of phosphates in the treatment of municipal wastewater. The water treatment sludge was fed directly into activations for experimental purposes. The concentration of phosphates went down below 2 $g.m^{-3}$. The fed sludge was the re-used water treatment sludge containing 50 $g.m^{-3}$ Fe. In order to reach 1 $g.m^{-3}$ P at the outlet, the required feeding dose was 130 $g.m^{-3}$ Fe. This also improved sedimentation properties of the activated sludge and the sludge volume index was decreased.

Precipitation takes place when the phosphates are removed from the wastewater by means of the ferric salts. Once the water treatment sludge with iron contents is used for the phosphate removal, adsorption only takes place. Typically, the reaction of phosphorus with marginally stable OH groups of ferric oxide hydrates is regarded an exchange reaction. Unlike ion adsorption that takes place only with surface groups charged with opposite charges, the adsorption of phosphorus is considered to be a specific adsorption that results in relatively stable surface complexes [17].

Experiments were also carried out in order to check the efficiency of the phosphorus removal by means of the alumina water treatment sludge. The dried alumina sludge was used as an adsorption agent for disposal of the phosphorus from the municipal wastewater. In case of the air-dry fine water treatment sludge with the grain size of 0.125 nm, the adsorption capacity was between 4 – 15 mg $PO_4^{3-}.g^{-1}$ of sludge [18]. In acid environment, the adsorption capacity increases. The dewatered and dried sludge can be used as a supporting agent for removal of phosphorus from wastewater treatment plant, for instance, for discharge of the wastewater into tanks [19].

Re-use of the sludge in municipal wastewater treatment plants can have negative effects too. The total volume of the sludge increases and the sludge cannot be decomposed by biological procedures. Consequently, the sludge handling system becomes more loaded. This can also influence the activation processes. Such effects would need to be verified in model experiments or semi-scale tests [20].

In this context, it would be advisable to investigate possible re-use of the alumina sludge for removal of phosphorus in the wastewater treatment.

Using the sludge as an admixture for production of cement.

Iron plays an important role in production of cement. The contents of iron in kiln-burnt alite is from 1 to 2%. In case of Portland cement, the clinker content ranges from 3 to 5 per cent.

Following materials are used typically to carry the iron:

- primary raw materials, this means low-quality iron ore
- waste materials
  - pyrite cinder from calcination
  - synthetic hematite from hydro-metallurgical zinc recovery

The iron sludge can be disposed freely if used as an admixture into cement. A full-scale test was carried out with the sludge from the Torgau waterworks in a cement kiln in Karsdorf [21]. The sludge was dewatered in a mobile filter press. The dry weight was 35 – 40 %.

The sludge had to be dried up more so that it could be used in the cement industry. Three drying alternatives have been investigated into:

- drying together with the grinding

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- drying in a fluidised bed
- mixing with a dry material

The drying in a fluidised bed proved to be the most simple and economic solution for drying of the iron sludge.

Results of the full-scale test in the KARSDORF cement mill is given in Tab. 4 [21] :

Tab. 4 Results of the full-scale test when the sludge was used as a admixture for the cement

	Norwegian pyrite cinder	Iron sludge from Torgau:	
		filter cake	thermic drying
Fe_2O_3 in the material (in %)	59	20	49
Water in %	8	64	10
Heavy metals (without manganese) in $mg.kg^{-1}$	2 342	398	398
Share of manganese in $mg.kg^{-1}$	149	9870	9870
Manipulability	good	satisfactory	good
Availability:	not warranted for the future	available on a long-termed basis, the quantity is not enough	
Cinder mineralisation	no deviations have been proved		
Cinder grindability	no deviations have been proved		
Whiteness index of cement	no deviations have been proved		
Emissions: - in a form of gas	lower than in case of pyrite cinder		
- in a form of dust	no deviations have been proved		

The results above indicate that the iron sludge can be used as an admixture for production of cement. It was permitted to introduce this method in operation. The sludge from individual plants is different and raw materials used for production of cement differ too. Therefore, it is recommended to carry out a small-scale test followed by a full-scale test in order to check whether the sludge can be used.

Using of the sludge in agriculture

Concentration of organic substances in the dry weight and consent of acceptable food-stuff play an important role for the use in agriculture. According to latest knowledge provided in the guidelines issued by the Czech Republic's Ministry of Agriculture, heavy metal limits are vital for the use in agriculture.

Samples of the sludge from the water processing plants in Podhradí and Nová Ves were analysed on the basis of the methodology [22]. Results are listed in Tab. 5 [23].

Tab. 5 Composition of the sludge to be used in the agriculture

Sample	Ignition loss (organic substances) in dry weight	Concentration of $CaCO_3$	Acceptable food-stuff mg.kg^{-1}		
	%	%	p	K	Mg
Sludge from Podhradí	60.8	none	53	78	102
Sludge from Nová Ves	52.4	none	23	50	176
Acid sludge from Podhradí - lime neutralisation	43.2	5.5	10	38	64
Acid sludge from Podhradí - dolomite limestone neutralisation	44.3	3.5	10	46	330

The analysed samples contain rather high concentration of organic matters in the dry mass. This corresponds roughly to the contents of the organic substances in the municipal wastewater treatment sludge. Calcium carbonate is contained only in neutralised samples of the acid sludge (it is understood that the acid sludge is the sludge after recovery of aluminium sulphate).

Regarding the concentration of the acceptable food-stuff pursuant to farming land criteria, the results are following:

- concentration of phosphorus is low to medium, with the acid sludge sample the concentration of phosphorus is very low

- the concentration of potassium ranges from low to very low

The sludge from Podhradí contained a medium level of magnesium, while the magnesium concentration in the sludge from Nová Ves was acceptable. For the lime neutralised sludge and dolomite limestone neutralised sludge the concentration was low and high, respectively.

Generally, the concentration of the organic substances and food-stuff is such that the sludge can be used in the agriculture.

Concentration of heavy metals is important too. An analysis was carried out to find out the concentration of elements in the sludge produced in the water processing plants in Podhradí and Nová Ves u Frýdlantu n.O. (Tab. 6) [23] :

Tab. 6 Concentration of heavy metals in the sludge to be used in the agriculture

Sample identification	Total concentration in mg.kg^{-1} Zn Cu Pb Cd Cr Ni					
Sludge from Podhradí	46	41	114	1,04	41	18,9
Sludge from Nová Ves	3	31	24	0,83	37	12,0
Acid sludge from Podhradí - lime neutralisation	9	38	13	0,23	31	12,3
Acid sludge from Podhradí - dolomite limestone neutralisation	8	27	9	0,12	20	6,6

According to the Ministry of Environment's Decree No. 382/2001 Coll. on re-use of treated sludge in the agriculture, limit concentrations of toxic metals and hazardous substances from wastewater treatment plants are as follows:

Cadmium max. 5 mg.kg-1 of dry weight

Lead max. 200 mg.kg-1 of dry weight

Chromium max. 200 mg.kg^{-1} of dry weight

AOX max. 500 mg.kg^{-1} of dry weight

PCB max. 0.6 mg.kg^{-1} of dry weight

The sludge that meets the criteria above can be used in the agriculture and applied directly on fields. It is clear that all analysed sludge has not exceeded the limits set forth for the wastewater treatment plants. When evaluating properties of the water treatment sludge, it is essential to reasonably apply regulations application to wastewater treatment sludge [24], because special regulations governing the water treatment sludge do not exist.

It follows from the analyses and experiments that standard alumina sludge from water processing plants in the Czech Republic can be used in the agriculture. It is however necessary to control the quality of the sludge.

Experiments were also carried out with the alumina sludge produced in the water processing plant in Harwood´s Mill, Newport, USA. The aim was to monitor crop of fescue grass and contents of metals in plants [25]. During coagulation, the aluminium sulphate transforms into alumina hydroxides that are similar to alumina hydroxides present naturally in soil. The aluminium hydroxide can increase a buffering capacity of the soil and to increase adsorption of some ions or compounds. The adsorption can be either favourable or harmful, depending on the characteristics of sludge and types of plants. In particular, the contents of usable phosphorus in the soil can decrease, or alumina toxicity for plants or withdrawal of heavy metals in sludge by plants can be influenced. Below are conclusions drawn on the basis of the study:

- The alumina sludge slowed down the growth of the fescue grass because it blocked phosphorus in the soil
- Application of another phosphorus increased the crop of the fescue grass by decreasing the phosphorus deficit caused by the sludge.
- In case of 2% sludge loading and double quantity of the phosphorus (exceeding the recommended quantity on the basis of land agronomy tests – 50 mg of phosphorus per kg of soil), the phosphorus deficit disappeared.
- The sludge loading increased the concentration of Mn in vegetable tissues, the influence of the higher Mn concentration on the growth of the fescue grass was, however, very little.
- The sludge loading increased the concentration of Cu in vegetable tissues. The Cu concentration in the tissues was however in standard interval and could not influence the growth.
- The concentration of limestone used during the study did not influence the crop of the fescue grass considerably.
- The dosing of the sludge, phosphorus and limestone did not influence the concentrations of K, Ca, Mg, Zn, Fe, B and Al in fescue tissues considerably.

Field experiments were carried out with the application of the alumina and iron sludge in the soil [26]. The soil structure improved and the placing of the sludge in the soil proved to be a preferred solution for light soil that was not influenced negatively. Vegetation was good and yields did not decrease. Furthermore, more humus was present in the soil.

It is possible to use the sludge in the agriculture, but due check for heavy metals is necessary.

CONCLUSION

In the water treatment, waste products – the water treatment sludge – is produced. The most typical method for processing of surface water uses alumina coagulants that produce the sludge containing 15 – 45% of alumina. It is possible to recover the alumina from the sludge in the water treatment.

Those methods are not economical so far, if compared to the application of new coagulants. They might become of importance if it is required to decrease the quantity of wastes produced by water processing plants dramatically. Those methods can be also used if there is a lack of aluminium sulphate – for any reasons. Therefore, it is essential to pay attention to such methods and be prepared for their use. It is also perspective to use the iron and aluminium sludge for treatment of municipal wastewater. The sludge is typically used for removal of phosphorus. The sludge can be also used as an admixture for production of cement. The main objective of the mentioned processes is to minimise the quantity of wastes that need to be disposed.

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RESUMÉ

Odpady z úpraven pitné vody, pod souhrnným názvem vodárenské kaly, jsou charakteristické značnou různorodostí chemických i fyzikálních vlastností. Na vlastnosti a složení kalů má vliv kvalita surové vody, technologický proces a stále se rozšiřující počet procesů, používaných při úpravě vody.

Problematice vodárenských kalů dosud nebyla věnována náležitá pozornost. Dosavadní provozní praxe dosud směřovala k sedimentaci odpadních vod a následnému zahušťování suspenzí, v některých případech i odvodňování kalů. Zahuštěné, případně odvodněné kaly, jsou většinou skládkovány.

Článek se zabývá vznikem a složením vodárenských kalů s ohledem na jednotlivé druhy vod a použité technologie včetně nových postupů s využitím membránových technologií. Podrobněji se uvádí možnosti využití flotace v procesu úpravy vody. Jsou uváděny postupy likvidace vodárenských kalů včetně jejich posouzení s ohledem na ochranu životního prostředí. Hodnoceny jsou metody strojního odvodňování kalů včetně možnosti využití těchto postupů. Podrobněji jsou diskutovány metody rekuperace hlinitých vodárenských kalů. Cílem je rozšířit tyto metody s ohledem na snížení výsledné produkce kalů.

Z dalších metod je uváděno využití kalu v procesu čistíren odpadních vod. Jde hlavně o železité kaly, které mají široké použití jak u stokových sítí k vázání sulfidů, tak i ve vlastním procesu čištění městských odpadních vod při odstraňování fosforu. Jeví se účelné ověřovat možnosti využití také hlinitých kalů k odstraňování fosforu při čištění odpadních vod. Cesta snižování objemu kalů úpravou technologických procesů je perspektivní a pomůže řešit kalovou problematiku.

Jsou uváděny možnosti využití železitých kalů jako přísady při výrobě cementu. Je to způsob, jak odpad využít jako surovinu pro další odvětví. Další možností je také využití kalu v zemědělství a lesnictví. Jsou uváděny výsledky analýz kalu z pohledu obsahu živin, cizorodých látek, které mohou ovlivnit zemědělské využití. Z polních pokusů vyplývá možnost aplikace kalů do půdy s příznivými výsledky. Obdobně lze postupovat u lesních půd. Je diskutováno posuzování kalů z hledisek hygienických. Zejména problematika patogenních prvoků je značně aktuální.

Z dané problematiky vyplývá, že i u tak obtížného odpadu, jakým je vodárenský kal, existují cesty dalšího vývoje, a to jak v oblasti technologických procesů a jejich vlivů na tvorbu odpadních kalů, tak i v procesech zpracování využití kalů.