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PHYSICAL PROPERTIES OF SAND FROM THE WASTE WATER TREATMENT PLANTS

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Abstract

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The work is focused on characterization of selected physical properties of sewage sand from the waste water treatment plants. Sand is transported into wastewater mainly in areas with a combined sewerage system – principally in connection with rainfalls, in case of which it is transported through the sewerage system together with rainwater, but also (within smaller extents) due to leakages of sewerage systems or bad conduct of natural persons and legal entities. The main attention was focused on basic physical parameters such as content of total solid, ash free dry mass, density and granulometry. These material parameters are very often underestimated so the set of quality data is completly missing, as well as a background for designers of wastewater treatment plants. This paper should be quite useful e.g. for the purpose of technological equipment design in the region of South Moravia.

sand, waste water treatment plant, density, granulometry

INTRODUCTION

Municipal wastewater contains significant amounts of organic and anorganic materials so–called sewage sand, which should be separated mostly in mechanical treatment at the wastewater treatment plant by sand traps. As a consequence, more or less large quantities of this sewage sand arrive in the subsequent clarifying equipment and can lead there to caking or, in the extreme case, even to operating disturbances. A recycling of the sand is possible when a substantial reduction of the organic content is achieved, and if basic physical parameters are known. Mineral composition of sand captured in a mechanical treatment of the wastewater treatment plants is very diverse. Density of the sand varies depending on its composition. Sand that is included in the waste water is mostly inert material, which the rain washes away from the roads and sidewalks to sewerage system. Mineral composition of these materials is highly variable and differs from the location of the site. Among the minerals that are in this materials in varying proportions represented, such as granite, limestone, gabrodiorit, sand, etc. Densities of these materials are very similar and they are in the range 2510 $kg.m^{-3}$–2630 $kg.m^{-3}$ for granite, 2520 $kg.m^{-3}$–2630 $kg.m^{-3}$ for limestone, 2610 $kg.m^{-3}$–2720 $kg.m^{-3}$ for gabrodiorit (Pytlík, 2000). The sand density is approximately 2620 $kg.m^{-3}$ (Torgal and Castro-Gomes, 2006). It can therefore be assumed with some probability that, the quality of the physical properties of sand from the mechanical treatment of the wastewater will be very similar to crushed aggregates. The crushed aggregates are used in civil engineering for preparation of the various concrete. The values of concrete density lies between 2600 $kg.m^{-3}$–2700 $kg.m^{-3}$ (Topcua and Isikdag, 2008).

MATERIAL AND METHODS

Total solid, ash free dry mass

Ten samples of sewage sand from various Wastewater Treatment Plants in South Moravia region were used. The collection of samples was based on ČSN–ISO Standard No. 10381–6:1998 Soil Quality – Sampling – Section 6. On the day of collection, the respective samples were transported to Mendel University laboratory. The methodology applicable to physical analysis of sludge, i.e. determination of the total content of solids annealing residue and ash–free dry mass is stipulated in ČSN Standard No. 83 0550 (Section 3).

Total solid content and ash–free dry mass in sewage sand samples were determined by use of electric muffle furnace LMH 07/12 which is designed to measure incineration processes, drying, degradation, re–heating, thermal treatments etc. Analytical laboratory balances Radwag AS 220/X, for precise weighing with readability to 0.0001 g has been used. A well–mixed sample (10 g) was evaporated in a weighed dish and dried to constant weight in an electric muffle furnace at 103 °C to 105 °C. The increase in weight over that of the empty dish represents the total solids TS [%]. After total solid assessment the dish with sample is put back to electric muffle furnace at 550 °C. The increase in weight over that of the dish after total solid assessment represents the ash–free dry mass [%].

Density measurement

Analytical laboratory balances Radwag AS 220/X, for precise weighing, readability to 0.0001 g has been used. The below described method may be used for aggregates. A sample of sewage sand is to be deposited in water for 24 hours, then its surface is dried and it is weighed (m_1). A sample treated in the aforementioned manner is put into a glass pycnometer of volume 50 ml and the pycnometer is filled with water. All air bubbles are removed and water is filled up to the calibrated volume. The external surface of the pycnometer is dried and the whole pycnometer, including the sample, is weighed (m_5). Following its emptying, the pycnometer is weighed filled with water (m_6). The sample on a dish is dried at 105 °C and it is weighed (m_4). Subsequently, the density value is calculated.

$$\rho_p = \frac{\rho_v \cdot m_4}{m_1 - m_5 + m_6}\ [\mathrm{kg \cdot m^{-3}}], \quad (1)$$

where:
ρ_p ... density of sand [kg·m^{-3}]
ρ_v ... density of water [kg·m^{-3}]
m_1 .. weight of sample of sand inserted in pycnometer [kg]
m_4 .. weight of dried sample of sand [kg]
m_5 ...weight of pycnometer containing sample of sand [kg]
m_6 ...weight of pycnometer containing water [kg].

Granulometry

Important characteristics of aggregates are particle size distribution $R(x)$, cumulative distribution $P(x)$ and frequency distribution $y(x)$. These distributions characterize aggregates and can be very important in the design of mechanical equipment at wastewater treatment. The method used for granulometry was sieve analysis, in accordance to ČSN EN 933-1. Considering the nature of processed materials, the following set of standard screens was sufficient for our purposes: 0.063 – 0.125 – 0.5 – 1 – 2 – 4 – 8 – 16 [mm].

Particle size distribution

For a mixture of sewage sand grains particle size distribution indicates the weight of sand grains x_z larger than mesh size of the sieve x depending on the total weight (Rosin and Rammler, 1933).

$$R(x) = \frac{\Delta m \cdot (x_z > x)}{m}\ [\text{-}], \quad (2)$$

where:
Δm .... weight of sand grains with mesh size x and larger [kg]
m..........total weight of the sample [kg].

Course of particle size distribution is approximated by Rosin-Rammler formula (Rosin and Rammler, 1933):

$$R(x) = e^{-bx^n}\ [\text{-}]. \quad (3)$$

Of the two known values $R(x_1)$ a $R(x_5)$ and with the elimination of parameter b is possible to determine the coefficient of homogeneity of the sample.

$$R(x) = \frac{\ln|\ln R(x_5)| - \ln|\ln R(x_1)|}{\ln x_5 - \ln x_1}\ [\text{-}]. \quad (4)$$

Theoretically, the coefficient n varies within the limits (0, ∞). Value $n = 0$ characterizes polydisperse mixture of grains with a constant value of $R(x) = e^{-1}$. The value $n = \infty$ characterizes monodisperse mixture.

Cumulative distribution

Cumulative distribution indicates the mass ratio of grains sized $x_z \le x$ smaller than the mesh size of sieve x depending on the total weight.

$$P(x) = \frac{\Delta m \cdot (x_z \le x)}{m}\ [\text{-}], \quad (5)$$

where:
Δm .... weight of the sand on the sieve with mesh size equal with x [kg]
m..........total weight of the sample [kg].

Frequency distribution

Frequency distribution can be derived from the particle size distribution. Mass of grains of size 0 to x is just $P(x)$. The grain size interval $(x, x + dx)$ is therefore the mass percentage $dP(x)$. Mass ratio of grains fall on unit interval defines the frequency distribution. Area under the curve $y(x)$ over the interval (x_{min}, x_{max}) is equal to one.

$$y(x) = \frac{dP(x)}{dx}\ [\mathrm{m^{-1}}]. \quad (6)$$

RESULTS AND DISCUSSION

Samples of sewage sand collected at wastewater treatment plant contained different amounts of total solids and ash free dry mass. The results of basic measurements are shown in Tab. I. The results show the variability of organic material in the sewage sand, which, apart from the potential risks with regard to the presence of pathogenic micro-organisms can also cause problems in processing and utilization of sand in civil engineering, etc.

I: *Content of total solid and ash–free dry mass in sewage sand samples*

Sample from	Total solid [%]	Ash free dry mass [%]
Tetčice	95.40	2.15
Střelice	86.53	3.29
Zbraslav	91.81	1.58
Ořechov	77.19	7.15
Náměšť nad Oslavou	48.10	37.29
Blansko	76.10	20.93
Boskovice A	72.00	21.37
Boskovice B	85.34	4.51
Letovice	20.59	68.49
Jedovnice	20.03	56.64

Density of sewage sand

Samples of sewage sand collected at wastewater treatment plants contained various amounts of total solids and ash free dry mass. The obtain results of basic measurements are listed in Tab. II. Density of samples from Náměšť nad Oslavou, Jedovnice and Blansko could not be established due to the high content of organic solids, see Tab. I. Results shown in Tab. II are particularly important in regard to the dimensioning of the sand traps are often placed incorrect values of density 1500 kg.m^{-3} what is apparent density of the sand (Pytlík, 2000). This can cause particular problems in mechanical treatment at the waste water treatment plant especially sedimentation of organic material with the sand which is undesirable.

Screening analysis of sewage sand

Granulometry analysis results are shown in the figures 1–3 which are given various functions, particle size distribution *R(x)*, cumulative distribution *P(x)* and frequency distribution *y(x)* respectively. An approximation of particle size distribution and cumulative distribution has been done with results shown in table III. The results show that most samples were obtained with satisfactory coefficient R^2 for aproximation of logarithmic function of the general equation:

$$y = a \cdot \ln(x) + b \ [-]. \qquad (7)$$

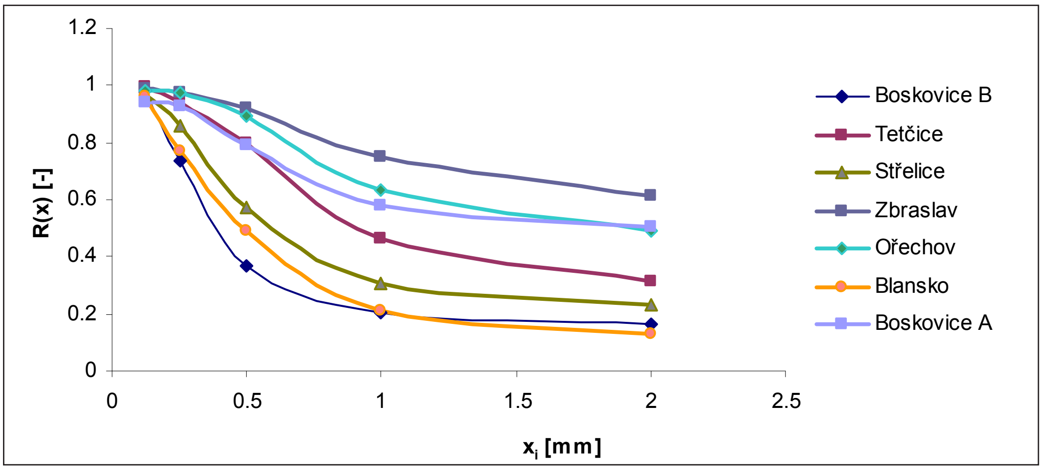
For other hypotheses will be necessary to test the data set expanded to include other long-term analysis to would clearly confirm or refute the findings made.

Coefficient of homogenity

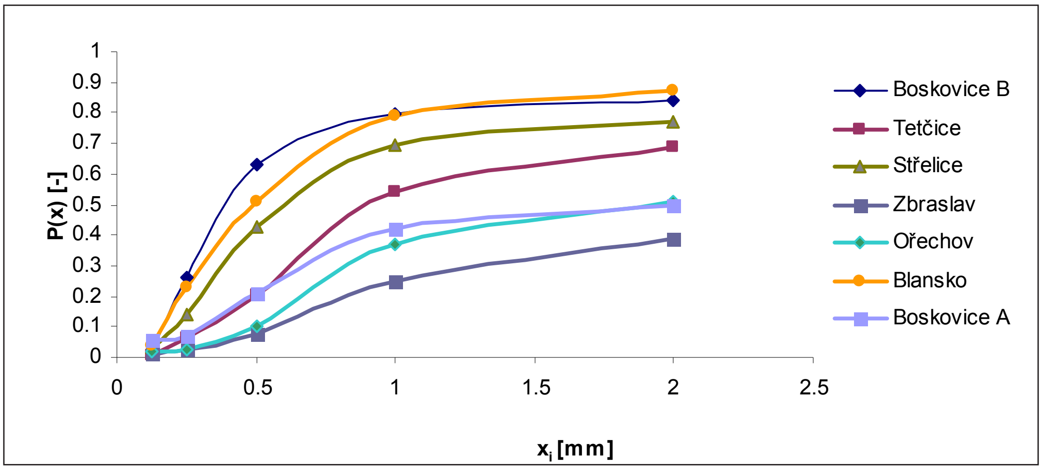
Samples of sewage sand collected at wastewater treatment plant have different values of coefficient of homogenity. The results are listed in Tab. IV, we can say that sewage sand is polydisperse mixture of grains with a constant value of $R(x) = e^{-1}$, acquiring

II: *Density of sewage sand samples*

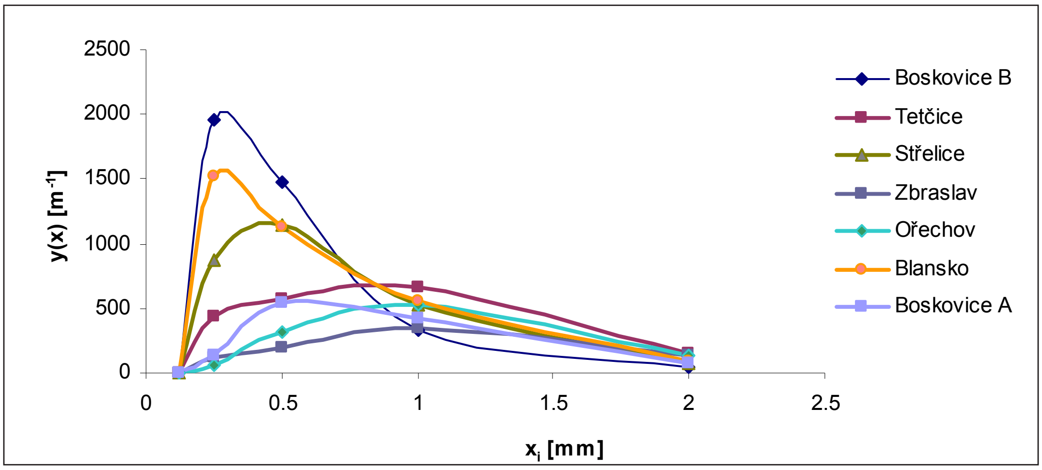
Sample from	Density [kg·m^{-3}]
Tetčice	3152
Střelice	2494
Zbraslav	2390
Ořechov	2410
Náměšť nad Oslavou	-
Blansko	2564
Boskovice A	2530
Boskovice B	2337
Letovice	-
Jedovnice	-



1: *Particle size distribution of sewage sand samples*



2: *Cumulative distribution of sewage sand samples*



3: *Frequency distribution of sewage sand samples*

III: *Values of the R^2 coefficients for individual samples of sewage sands*

Sample from	R^2
Tetčice	0.9421
Střelice	0.9664
Zbraslav	0.8954
Ořechov	0.8932
Náměšť nad Oslavou	-
Blansko	0.9771
Boskovice A	0.9407
Boskovice B	0.9311
Letovice	-
Jedovnice	-

values were in interval (0.89–1.92) containing various fractions showing no equitable distribution of these fractions. These may be an important finding for further possible of sewage sand utilization.

IV: *Coefficient of homogenity of sewage sand samples*

Sample	Coefficient of homogenity [-]
Tetčice	1.92
Střelice	1.35
Zbraslav	1.37
Ořechov	1.29
Náměšť nad Oslavou	-
Blansko	1.40
Boskovice A	0.89
Boskovice B	1.67
Letovice	-
Jedovnice	-

SUMMARY

Work deals with selected physical parameters of sewage sand. These physical properties are very important to design equipment for mechanical treatment of waste water and dimensioning of technological processes used there. The measurement of physical properties of sewage sand is often neglected, so the main aim of this work is to add the missing information.

Samples of sewage sands were collected from ten different wastewater treatment plants across Southern Moravia. First of all the organic portion of the sample was removed by washing in fresh water. Subsequently, individual samples were dried at 105 °C for 12 hours. Density was determined using a glass pycnometer, values are 2337 kg.m^{-3}–3152 kg.m^{-3}, corresponding to values of minerals reported in the scientific literature (Pytlik, 2000; Torgal and Castro-Gomes, 2006). For the granulometry the sieve analysis method has been used. The sieve analysis was carried out according to ČSN EN 933-1. Functional dependence of granulometric characteristics – particle size distribution *R(x)*, cumulative distribution *P(x)* and frequency distribution *y(x)* was performed according to the Rosin-Rammler. Having compared the results of individual samples there is showed considerable variation of the function. The course of particle size distribution is nearly identical for samples from Boskovice and Blansko, where the values of *R(x)* for individual fractions are almost identical. The only exception is 0.5 mm fraction, where the variation is about 25%. Coefficient of homogeneity indicated that all samples are polydisperse mixture. The highest conformity to size fraction, depending on the value of *R(x)* or *P(x)* was achieved with a logarithmic dependence on the sample of Blansko (R^2 = 0.977), the lowest then for the sample of the Zbraslav (R^2 = 0.895), other samples has values varied around the values R^2 = 0.950.

SOUHRN

Fyzikální vlastnosti písků z čistíren odpadních vod

Práce se zabývá vybranými fyzikálními parametry čistírenských písků. Tyto fyzikální vlastnosti jsou velmi důležité pro konstrukční návrh zařízení pro mechanické předčištění odpadních vod a dimenzování technologických procesů. Dosud bylo měření fyzikálních vlastností čistírenských písků spíše opomíjeno, proto si práce klade za cíl tyto chybějící informace rozšířit.

Vzorky čistírenských písků byly odebírány z vybraných čistíren odpadních vod na jižní Moravě. Bylo vybráno celkem deset čistíren. Odebrané vzorky byly nejdříve rozplaveny, aby organická část z měřeného vzorku byla odstraněna. Následně byly jednotlivé vzorky po dobu 12 hodin sušeny při teplotě 105 °C. Měrná hmotnost byla zjištěna pomocí pyknometru a pohybovala se v rozmezí 2337–3152 kg.m^{-3}, což odpovídá měrným hodnotám minerálů uváděných v odborné literatuře (Pytlík, 2000; Torgal and Castro-Gomes, 2006). Pro granulometrickou charakteristiku byla vybrána sítová analýza, jež byla provedena dle ČSN EN 933-1. Funkční závislost jednotlivých granulometrických charakteristik – rozsevová křivka *R(x)*, křivka četnosti *P(x)* a křivka propadu *y(x)* – byla provedena dle Rosin-Rammlera. Po srovnání rozsevových funkcí pro sledované vzorky se ukázala značná variabilita jejich průběhu. Průběhy rozsevových křivek jsou téměř totožné u vzorků z Boskovic a z Blanska, kde hodnoty *R(x)* u jednotlivých frakcí jsou takřka stejné, výjimkou je jen frakce 0,5 mm, kde odchylka činí přibližně 25 %. Koeficient stejnorodosti naznačil, že všechny vzorky jsou polydisperzní směsí. Nejvyšší shody v případě závislosti rozměru frakce na hodnotě *R(x)*, potažmo *P(x)*, bylo dosaženo při logaritmické závislosti u vzorku z Blanska (R^2 = 0,977), nejmenší potom u vzorku ze Zbraslavi (R^2 = 0,895), hodnoty R^2 pro ostatní vzorky se pohybovaly kolem hodnoty R^2 = 0,950.

písek, čistírny odpadních vod, měrná hmotnost, granulometrie

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