Quo vadis “Glass”?

Efficiency of glass beads as filter material confirmed – approval application according to DIN 19643 pending

Dipl.-Ing Eberhard Wistuba, ETC engineering & technology consulting GmbH, Burgau, Dipl.-Ing Gerhard Willert, Ingenieurbüro für Wassertechnik GmbH Empelde, und Dipl.-Geol. MBA Reinhard Klaus, Sigmund Lindner GmbH, Warmensteinach -

The topic of “glass beads as filter material” was the subject of many reports already beeing published in 2011 (see AB 03/11 p. 164 ff. (part 1) and 10/11 p. 627 ff. (part 2)).

Special glass spheres, technically known as “glass beads” (see Fig. 1), have been used as state of the art filter material for more than six yers in well building In early 2010 the first laboratory test were conducted to assess further applications in the water sector. Those tests showed that there was a potential for the use of glass beads in swimming pool water treatement.

At the turn to 2011 – in the author’s opinion probably the first time ever in the history of pool water treatment – glass beads were used in the public swimming pool at Michelbach near Schwäbisch Hall, in order to be extensively tested in a joint research project[1] in a practical application. There were first positive results already at the end of 2011, in detil beeing documented in part 2 of the aforementioned reports. So, the requirements for a lengthy practical test were set, by which the efficiency could have been proved, which is necessary and even compulsory for the official approval of this new “artificial” filter material made of glass for the use in swimming-pool water treatment.

Status Quo “Approval”

After almost four years of testing glass beads in in practice, an expertise by the Polytechnic (TU) Dresden[2] confirmed that the tested glass beads of type S were also suited for the treatment of swimming pool water. It should be noted here that this expertise was funded by he Bavarian State Ministry for Economy and Technology by means of an innovation grant as part of the research project “Homogenous filter bed made of inert glass bead filter material”. With this scientific and independent approval

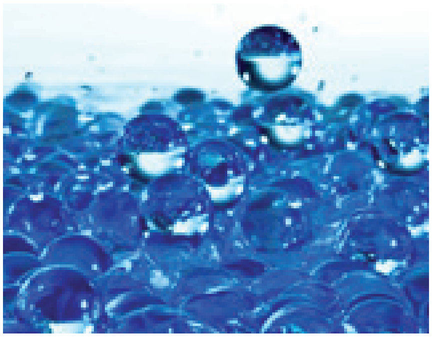

Fig. 1: Glass beads; photo credit: Firma Sigmund Lindner, Warmensteinach

Although already quite a number of suppliers claim to be able to provide with “approved” filter beads, glass beads have not yet been approved – neither according to DIN EN 12904 (for filter materials) nor to DIN 19 643 intended for swimming pool water treatment systems. The claims of the supplier are therefore incorrect and are often – intentionally or unintentionally – used and deceive the consumers. This was already noted at the autumn convention of the Technical Commission in Leipzig at the end of 2012 (see the minutes in AB 04/13 p. 254 ff.).

The presenters and authors have therefore stated that initially they tested several glass bead products in chlorinated swimming pool water. Some of the products were found to be unsuitable, because they released, in some cases large amounts of chlorine by-products (trihalomethane, bound chlorine). All of these glass beads were available on the market, but they were found to be unsuitable due to their material composition and/or their surface properties. During production and final treatment the surface can be manipulated, e.g. it was found that with magnetic beads certain separation rates could be influenced, OH groups can be manipulated, and often all sorts of chemically instable coatings could be applied, such as silane for glass beads for road marking paints.
So it is essential to ensure that the beads to be used for water treatment are suitable for this purpose.

The glass beads found to be suitable are all approved for the “filtration of water and production of drinking water” and have been awarded approval certificates for “food and drinking water” (e.g. HACCP approval for food[3], NSF approval[4], exclusion of silan, glycol and epoxy resin). Operators are therefore urgently advised that they insist on the presentation of the respective certificates before purchasing glass beads.

Application at the DIN (Deutsches Institut für Normung, German Institute for Standardization)

Currently, glass beads have not yet been approved, but this is due to change very soon, at least for the tested glass beads. Last autumn the application “for the development of a product standard for glass beads for water treatment” was as a matter of principle approved by the responsible Standardization Committee NA 119 04-02 AA “Water treatment” of the German Institute for Standardization, and the application including the standard draft are due for treatment (oder are beeing processed) before the end of this year.

Status quo “Other pilot facilities”

The special reports published in the AB Archiv des Badewesens (Archive of pool operators) found positive resonance both with the operators and the designers. The saving potential regarding energy and fresh water was the reason for this. But also the improved performance of the glass bead filters versus the sandfilters in Michelbach found great interest. The sceptical voices questioning whether the results can be reproduced in other pools may not be ignored.

This pilot run, however, was the initial spark for other facilities, which all converted to glass beads in the past years. So far, in Gøteborg and Kungsbacka in Sweden, in Maribor in Slovenia and in other European countries pilot facilities have taken up operations with permanent use of glass beads, including two Coca Cola plants. Not only in Europe,but also in the United States several facilities will be adapted in the course of this year, including filter facilities for potable water treatment.

In Germany further glass bead projects are in the planning phase, such as the indoor swimming pool in Schöningen. One of the largest facilities, the open air swimming pool Dellwig in Essen with probably the largest filters to date, is going to be changed over in the first half of this year.

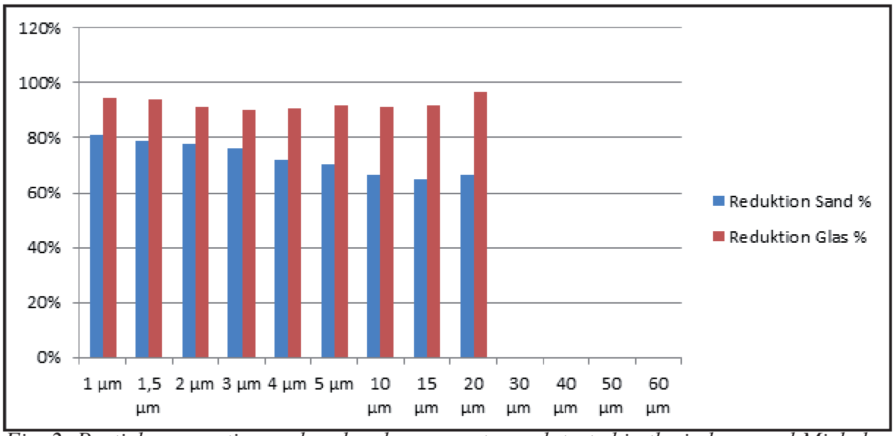

Fig. 2: Particle separation – glass beads vs. quartz sand, tested in the indoor pool Michelbach, March 1 – 7, 2011 (means); source: Ingenieurbüro für Wassertechnik, Empelde

Most recent results

The newest project, in a public swimming pool in the Spreewald (Lübben) in fact started operations a few weeks ago, but here the results are similar to those found in most other facilities:

- The filter performance of the glass beads was generally better than with filter sand.
- The backwashing speed could be reduced from 50 – 55 m/h (164 – 180 ft/h) to 20 – 25 (20 - 80 ft/h) m/h. By “halving” the backwash water speed an additional pump (and with it the increased electricity consumption) could be saved.
- The backwashing water volume was considerably lower than before the change-over. It was possible to reduce the backwashing water volume in the public pool in the Spreewald from 24 m^3 (840 ft^3) to less than 10 m^3 (350 ft^3) per backwasing cycle, which means savings of 60 %.
- The effective filter surface can be reduced by approx. 20 % when using glass beads. This means that the filter volume and the space required for the technical system can also be reduced, meaning even more savings.

Using glass beads means that new paths are taken in filter design. Currently, all design work is still partly empirically. The currently known, tried and tested design criteria will need to be adapted to the new filter material based on the practical trials and tests. Because of the improved filter performance the filter construction, regarding the filling heights, filter materials, filter and backwashing speeds, needs considerable changes and adaption.

This may sound very complex, but it can be easily explained if one considers the Kozeny-Carman equations and the results from Michelbach. Despite the effective surface of the glass beads being approx. 10 % smaller than in sand filters, there is a clearly better filter performance.

In Fig. 2 it is evident that the particles separated in the filter are, in some cases, by 35 % higher that with filter sand. Epecially after backwashingit was shown in the sand filter that for several minutes there were high particle numbers in the filtrate, something that didn´t happen after backwashingthe glass beads.

x [mm] at Q3=10.0 %	0.475
x [mm] at Q3=50.0 %	0.584
x [mm] at Q3=90.0 %	0.791
Sm [cm^2/g]	40.839
p3 (0.4000 mm.0.8000 mm) [%] =	90.44
mean b/l3	0.947

Grain class [mm]	p3 [%]	Q3 [%]	b/l3
0.000 - 0.315	0.04	0.04	0.528
0.315 - 0.355	0.15	0.19	0.609
0.355 - 0.4	0.75	0.94	0.773
0.400 - 0.5	15.84	16.78	0.947
0.500 - 0.6	38.69	55.47	0.947
0.600 - 0.7	19.47	74.94	0.947
0.700 - 0.8	16.44	91.38	0.953
0.800 - 0.85	5.88	97.26	0.964
0.850 - 0.9	2.07	99.33	0.961
0.900 - 1000	0.67	100	0.946

Table 1: Typical Camsizer® analysis on the example of glass beads (0.4 – 0.8 mm sorting) SiLibeads® Type S 5219-7, Lot # 1210004; source: company Sigmund Lindner, Warmensteinach

Fig. 3 (above) and Fig. 4 (left): Manual fillling of small containers, dust-free; left: Michelbach, right: Lübben; photo credits: ETC, Burgau

With particle separation values between 90 and 98 % the quality is not far from that of the new membrane filter technologie.

An explanation for the improved filter performance is probably found in the homogeneous pore system in combination with the surface of the glass beads. But this will certainly require further tests. The final report from the TU Dresden did not add any news to the results from our tests. In the coming years there will have to be some more research and development from all sides.

It is a fact – as evidenced in the subsequent projects – that with glass beads smaller surfaces are sufficient to achieve at least the same filter performance.

These surfaces are considered according to Kozeny-Carman:

$$k = \frac{\phi^3}{5(1-\phi^2)S_m^2}$$

Permeability Kozeny-Carman [m^2]

$$S_m = q\ s;\ s = \sum_i \frac{P_i}{r_i}$$

$$s = q \int_{r_1}^{r_2} \frac{1}{r\,(r_2 - r_1)}\,dr = q\,\frac{Log(r_2) - Log(r_1)}{r_2 - r_1}$$

Specific surface [m^2/m^3]

The equations explain that the ratio between grain size gradation and filter surface is inversely proportional, i.e. the smaller the difference between bottom and top maximum in filter material grain size, the larger the filter surface and with it the filter performance will be.

Ideally, with identical grain sizes, or r2 = r1, there is a limit 1/r2*q.

An example to clarify this: The size of all beads is exactly 0.75 mm (= a radius of 0.375 mm). This means that the maximum possible specific surface will be

1/0.375 *3 * 1,000 = 8,000 m2/m3

If the gradation is, for example, expanded to a range of 0.75 to 1.00 mm, a commonly available fraction, the specific surface is already reduced to 6,900 m2, or approx 15 %. If the spectrum is expanded even further, for example to 0.75 to 1.2 mm, this would mean a reduction of the specific surface by more than 20 %.

Or in other words: The filling would have to be increased by 20 % in this case in order to achieve the same filter performance, and the filter itself has to be larger by 20 %. All this would mean considerable extra costs for the filter volume and required technical space.

A fraction with identical diameters would be optimum. Production of such homogeneous beads is feasible, but this would make the filter considerably more expensive. That is why in practice one will have to find a compromise and – as far as possible, use glass beads available on the market.

Currently glass beads with special fractions are being produced, for example from very fine (0.1 – 0.2 mm), over medium (0.5 – 0.7 mm) to very coarse > 2.5 mm. This fits from the size (diameter) and is also sufficiently close in the distribution.

Table 1 shows typical distributions which are possible in practice and how they should look like.

More than 97 % of the glass beads of this production lot have a diameter between 0.4 and 0.85 mm. The ratio of fines (fine material), such as with filter sands with up to 5 % abrasion , is less than 0.04 % with glass beads and negligible – this is also evident when filling the filters with glass beads, which is virtually dust-free (see Fig. 3 and Fig. 4).

On the basis of these findings it would be logical to install the finest possible fractions. But this is where the effect of the growing resistance knocks in, because the finer the beads are, the higher the head loss gets, which means rising electrical currents and consumption. With increasing flocculation intensity the filtration shifts from the desired spatial filtration to a surface filtration.

It is therefore not necessary to make the beads too small, because the assumption that the smaller the filter material the better the filter performance will be applies only down to a certain size. This was already shown in the Michelbach reports to the investigations by Dr. Ing.- Rudi Winzenbacher of the Zweckverband Landeswasserversorgung (administration board for state water provisions) in Langenau. He stated in his research report that “the filter quality is not improved as expected when the filter sand grain size is reduced” (3) from 0.7 – 1 mm to 0.4 – 0.8 mm.

This leads to the assumption that from a certain level on a further reduction of grain size will not result in any improvements, especially when taking the resulting disadvantages of the significantly higher head loss into account. This is actually correct because the calculated relative pressure loss will more than double when the bead size is reduced from 0.75 – 1.0 mm to 0.4 – 0.8 mm. Even finer fraction are technically possible, but would in practice be nonsense.

Also to be considered must be the requirements on filters, especially according to DIN 19 643 concerning the dosage of powdered activated carbon (PAC). This is the reason why for most applications the very fine glasbead fractions are unsuitable anyway because for the top layer only filter material with a grain size greater than 0.7 mm can be used.

Using the Kozeny-Carman equation for the specific surface the required filling volume will be calculated on the basis of the respective bead size.

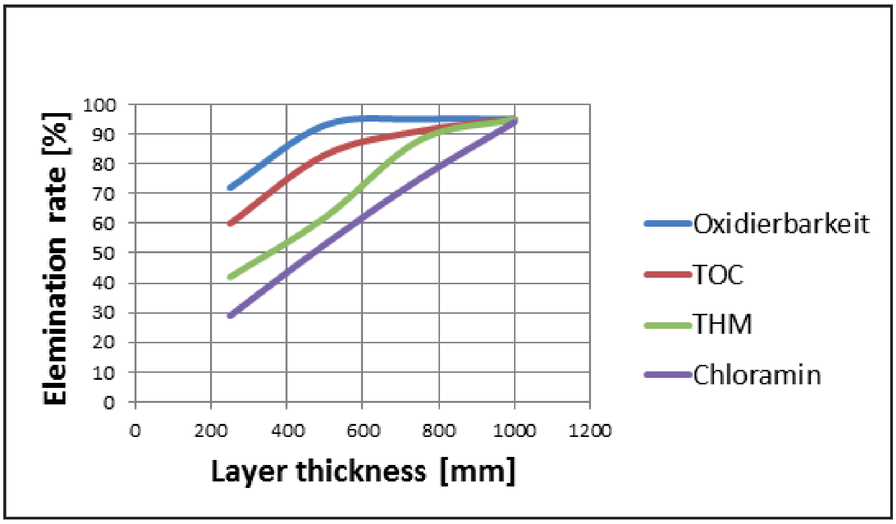

Fig. 5: Elimination rates depending on filter layer thickness, glass beads SiLibeads®, Type S 0.75-1.0 mm; source: ETC, Burgau

The layers should be not thinner than 400 mm, if possible (see Fig. 5); but more than 1000 m is also not necessary for improved performance.

The bottom layer or support layer should be dimensioned accordingly. While “three layers” in the Michelbach pilot project have been installed analog to the three gravel grades „supporting layer“ of sand -filling heights (3 x 100 mm)-, in the subsequent project a setting with only one supporting layer was found to be better: 70 – 100 mm (see Fig. 6) with glass beads, grain size from 0.75 mm to 1,00 mm, ensuring sufficient coverage of the filter nozzles and provide an optimum distribution of the water during filtering as well as during backwashing. In combination with anthracite the design according to Kozeny-Carman has only to be changed considering that the specific surface of anthracite has to be taken into account. In this case the number of glass beads can be accordingly lower.

Backwashing

The considerably lower backwashing speeds using glass beads have already been mentioned above. In Michelbach this was not implemented, although this would have been ppossible, but the tests were run with the same flow and operating conditions as with the installed sand

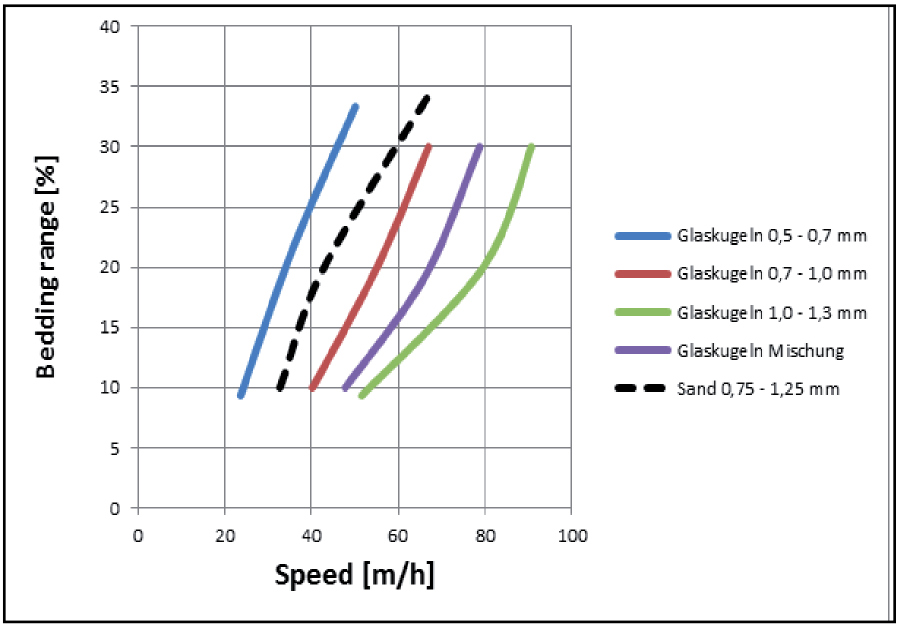

Fig. 8: Backwashing graphs glass beads / filter sand with a uniform water temperature of 283 K; source: ETC, Burgau

filter, in order to be able to make direct comparisons.
In the current projects the backwashing speeds were reduced as much as possible by means of manual (plumb line) tests. In some places of the filter a plumb line was sunk without resistance to the bottom of the nozzles. This ensured that the entire filter bed is in motion and the flaking of most of the seperated particles and from the filter beads is guaranteed.

In the preliminary tests it was found that for a complete filter bed mixing bed expansion of maximum 5 % was sufficient. The exact values, corresponding to the backwashing of sand depend greatly on the backwashing water temperature and the grain size, were in practice determined using the respective filters.

It was clear that the backwashing speeds were lower than with sand filters. But the fact that the backwashing speeds were as low as 20 to 28 m/h (66 to 92 ft/h)(see Fig. 8) with a bed expansion of more than 10 % would be totally sufficient was a surprise for all participants.

Fig. 6: 80 mm support layer, glass beads 0.75 – 1.0 mm; photo credit: ETC, Burgau

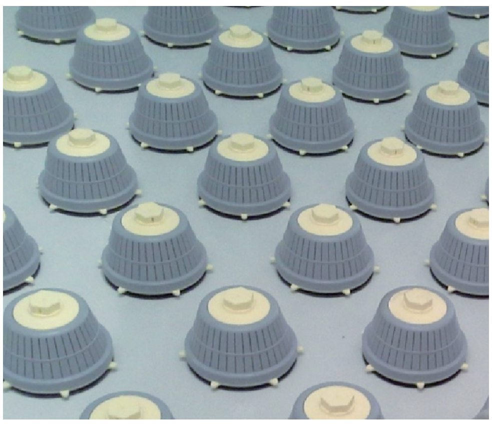

Fig. 7: Typical filter jets with slot widths of 0.5 mm; photo credit: ETC, Burgau

It should, however, be noted that this may vary from system to system and must be adjusted depending on the facility, or determined empirically.
It must also be considered that the backwashing speed is not too low, as otherwise the seperated particels can not be removed properly – especially when restoring existing filter tanks. As a standard, free board height is considerably higher after changing the material, as fewer glass beads are required. During backwashing this may result in the fact the heavier paticles are not perfectly rinsed out.

A good median according to recent experience is at 25 m/h (82 ft/h) backwashing speed.

Then the next great adantage becomes evident: As the backwashing speed with glass beads compared to sand is nearly 50 % a second pump is no longer required. This saves space, piping and investment costs.

Summary

Glass beads provide considerable advantages in relation to filter performance, water and energy consumption, but are not yet standardized.

The application of non-standardized procedures – prodecures not corresponding to the accepted state of the art – mean contractual and liability risks for designers, facilty constructors ans operators. An inclusion in the regulatory documents of technology (DIN 19 643 and a product standard for glass beads) is intended and will probably be implmented in the near future.

Until then, when using glass beads as filter material, it must be considered that no contractual or liability restrictions and risks are apparent. Thus especially operators and clients must be advised/ informed that the standardization is applied for, but has not been approved yet. This is especially important when considering the filling height, the grain sorting and the filter and backwashing speeds, which are currently based on empirical test results.

So only designers, construction companies and suppliers, experienced in the development of water treatment facilities for swimming pools, should be commissioned. In addition, the quality of the installed glass beads must be certified by independent certificates.

Projections

Some improvements resulting from the introduction of artificial filter materials such as glass beads have been investigated . But there must be further endeavours to investigate all possibilities, so that the results can be optimally used in water treatment.

Filters are, in effect, "the single most element in the treatment facility for swimming pool water", and the same can be postulated for filter materials being used. Currently there is definitely need for action. In specialist literature there is very little to be found in experience horizon, which makes it necessary in future to work hard on it.

Finally a small swipe shall be permitted towards potable water production: Ever since the beginning of the construction of wells only one material was available. It is not surprising that glass beads were smiled at contemptuously by experts. But meanwhile/nowadays, glass beads have become an integral and essential component of the entire technology. In view of the current requirements for the improvement of energy efficiency and sustainability of resources glass beads must be intesivly investigated ans used consistently.

Notes / Literature

1) Protagonists of the joint research project:

Dr. Renate Lorenz-Lauermann and Ursula Bräuer, Gesundheitsamt (health services) Schwäbisch Hall (Überwachung)(monitoring)

Peter Busch, Stadtwerke (utilities) Schwäbisch Hall (Betreiber des Hallenbades Michelbach) (operators of the municipal pools)

Dr. Daniel Pacik, OEBA-Institut, Dresden, and L.V.H.T.-Institut, Mülheim an der Ruhr (Analytik)

Jürgen Elgg und Jürgen Väth, Wassertechnik Wertheim GmbH, Wertheim (producer of the treatment facility and the filters at Michelbach)

Gerhard Willert, Ingenieurbüro für Wassertechnik GmbH, Empelde (Particle measurements)

Sigmund Lindner GmbH, Warmensteinach (manufacturer of SiLi-Beads Typ S, Glass beads)

Dipl.-Phys. Walter Markiel and Dipl.-Ing Eberhard Wistuba, ETC engineering & technology consulting GmbH, Burgau (Project management and evaluation)

2) "Beurteilung von Glaskugeln hinsichtlich ihrer Eignung als Filtermaterial zur Aufbereitung von Schwimmbeckenwasser", (Assessment of glass beads regarding their suitability as filter materials for the treatment of swimming ool waters), Abschlussbericht (final report) by Dr.-Ing. Irene Slavic and Prof. Dr.-Ing. Wolfgang Uhl, 20.05.2013, TU Dresden, Institut für Siedlungs- und Industriewasserwirtschaft, Professur Wasserversorgung (Institute for settlement and industrial water management, professureship water supply)

3)Hazard Analysis and Critical Control Points, applicable on companies and products coming in contact with food

4)National Science Foundation (NSF)

5) Dr.-Ing. Rudi Winzenbacher, Untersuchungen zur Effektivität verschiedener Filterschüttungen bei der Trinkwasseraufbereitung im Wasser werk Langenau (Research in the efficiency of various filter fillers for drinking water treatment at the drinking water provision works at Langenau), gwf Wasser/Abwasser, January2011, pp. 84-92/89