Dirk Lechtenberg, MVW Lechtenberg & Partner

Dried sewage sludge as an alternative fuel

In this article Dirk Lechtenberg from MVW Lechtenberg & Partner gives an overview of dried sewage sludge as an alternative fuel source. This is the second excerpt from MVW Lechtenberg & Partner's Alternative Fuels & Raw Materials Handbook. Due to be published in the summer of 2011, the handbook will give an insight into over 80 different types of alternative fuels and raw materials with detailed descriptions of the availability, common use and practice in the cement industry. This includes processing considerations, the influence on the environment, clinker production and the economics of the various alternative fuels.

Above: Dried sewage sludge being loaded onto a ship in Athens, Greece.

Waste-water treatment plants for industrial or municipal water all over the world produce residues, so-called sludges, which are becoming more and more popular as alternative fuels in the cement industry. Especially common is the use of waste heat from the production of clinker for drying of dewatered sludge. This has several environmentally-friendly features, namely the use of waste heat, the environmentally-friendly use of dried sludge, the offering of an environmentally-friendly service to the public, reduced fossil fuels use, reduced CO_2 emissions and saving costs.

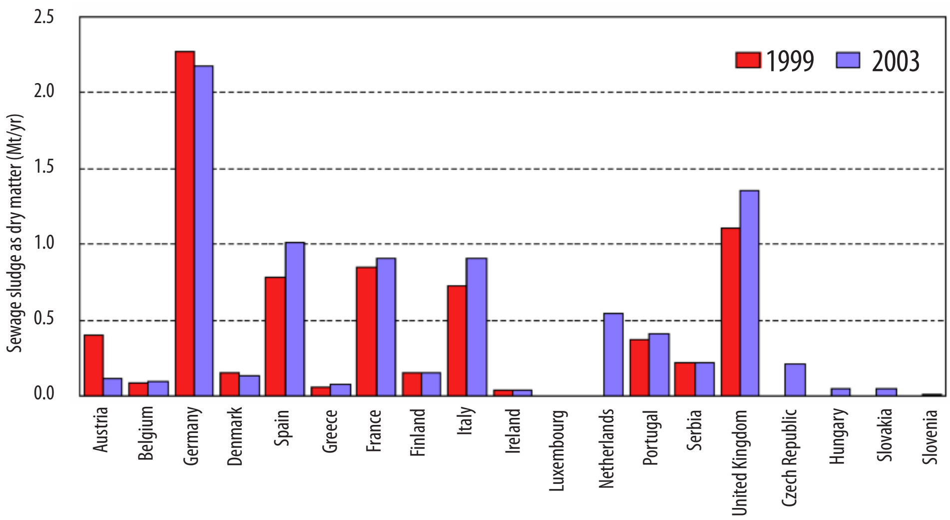
Sludge or slurry from the biological treatment 190811*/12

During biological treatment the organic substances in sludges are reduced by micro-organisms with the help of the metabolism process. The degradation process takes place in an aeration tank, where substrates are adsorbed first and then due to microbiological activity, water, CO_2 and new biomass are released. The raw sludge is removed by way of a settling tank and filtration. Thus the aerobic activity is maintained in a digester.

The raw sludge has about 5% solid content and the stabilised sludge is around 10% solid. The sludge will then be dewatered, for example by adding conditioning agents and will then be mechanically dehydrated by a chamber filter press and to a point where it possesses 30% to 40% dryness. Depending on the method of disposal it can be dried further by using thermal dryers. This sludge has a high calorific value, which may be greater than 11,000kJ/kg when dehydrated.

The consistency and composition of dehydrated sludge is similar to sewage slurry from treated municipal waste water. The dry substance contains organic material (40% to 45% by weight) and minerals (55% to 60% by weight) with reference to initial composition including metals, metal compounds, petroleum hydrocarbons and organic pollutants with halogens or halogen free. Sewage sludge is normally available in large amounts in municipal or industrial waste water treatment plants. The diagram shows the annual amount of sewage sludge in European countries expressed as dry matter in 1999 and 2003. In Germany about 50Mt of sewage sludge with 5% solid content is generated daily (**Source:** Dr.-Ing. Manfred Tomalla, *'Entwässerung von kommunalen und industriellen Schlämmen'*).Table 1 provides some analyses for some selected wastes types, which can reveal information about the chemical composition of the waste. For each type of waste given in the table, the number of existing analyses are given.

Below - Figure 1: Annual amount of sewage sludge (dry matter) produced in European countries. (**Source:** Emsher).



		190805		190811		190813*		190814	
Parameter	Unit	(N)	Average (or single value)	(N)	Average (or single value)	(N)	Average (or single value)	(N)	Average (or single value)
Calorific Value	kJ/kg	148	12309	3	14272	7	6926	21	7380
Calorific Value	kcal/kg	148	2940	2	3408	20	1654	-	1762
Flash point	C	1	90.0	1	75	2	82.5	5	90.8
Dry substance	%	30	17	8	36.62	41	54.56	270	44.54
Moisture	%	30	72.9	2	60.75	41	47.51	76	60.39
Lead	mg/kg	5262	93.12	6	79.83	41	1030	101	134.85
Cadmium	mg/kg	5264	1.97	5	8.82	40	239.5	91	3.79
Mercury	mg/kg	5199	0.92	7	10.98	35	28.51	95	5.91
Arsenic	mg/kg	310	5.67	5	16.58	33	139.26	37	34.91
Chromium	mg/kg	4982	61.61	5	105.65	39	3117	85	381.94
Copper	mg/kg	5257	335.16	6	84.08	37	2661	80	5883
Nickel	mg/kg	5280	39.73	6	154.91	39	6828	83	87.91
Tin	mg/kg	13	205.93	5	660.44	18	117.9	6	2868
Zinc	mg/kg	5236	1004.87	5	776.6	41	10993	100	1862
CN (total)	mg/kg	-	-	-	-	15	75.02	40	6.43
PAK-EPA (total)	mg/kg	254	12.12	1	1734.0	15	17.94	10	139.67
Bromide	%	1	0.1			1	0.006	3	0.07
Chloride	%	15	1950	4	0.1	12	0.33	24	0.38
Fluoride	%	8	0.06	2	0..05	9	0.096	26	167.34
J	%	1	0.1	-	-	-	-	5	0.07
S	%	9	1.48	3	1.11	14	0.55	29	0.93

Left - Table 1: Properties of different sewage sludges. N = amount of analyses.

Left: Transport of sewage sludge by silo truck. (**Source:** Peter J. Aebi; gsa Info 2_2008 Abfälle und Rohstoffe).

The use of sewage sludge as alternative fuel in clinker production is the most sustainable option. Due to the high temperature in the kiln the organic content of the sewage sludge is completely destroyed. The sludge minerals are bound in the clinker after the burning process. The use of dried municipal sewage sludge in cement plants is common practice.

In 2005 the Swiss cement industry used 39,878t of dried sewage sludge, 16% of the total used tonnage of alternative fuels. In 2006 the quantity increased to 54,964t of dried sewage sludge, 22% of the total. (H. Widmer. *'Usage of sewage sludge in cement industry: An act of sustainability'* and *'The Swiss way of sewage sludge disposal.'*)

In Germany around 157,000t of sewage sludge was used in 2005. (German Cement Association: '*Activity Report 2005-2007,*' p. 25]. In 2006 around 200,000t of dewatered municipal sewage sludge (75% H_2O, CV < 8MJ/kg) and around 40,000t of dried municipal sewage sludge (8% H_2O, CV ~ 10MJ/kg) was used. (M. Oerter).

A research project of the German Cement Association (Research project No. 14884 N) describes the results of usage of mechanically dewatered sewage sludge (MEKS) and dried sewage sludge (TKS) in three German cement plants. MEKS were fed into the calciner whereas TKS were fed into the main burner.

The substitution of 10% of the heat demand by TKS showed no significant influence on the specific heat demand, whereas the appropriate usage of MEKS in the calciner increased the specific heat demand by ~250kcal/kg clinker.

The investigations of inner and outer kiln mass balances showed a slightly increased input of mercury. However, the emissions of mercury did not exceed the (daily average) emission limit of 0.03mg/Nm^3. The increased mercury circulations were discharged by the specific kiln operations, such as a bypass.

Calorific value

The calorific value of sewage sludge depends on the organic content and the moisture content of the sludge.

Right - Table 2: Fuel substitution calculation. (*average calorific value of sewage sludge 17% dry substance). (**average calorific value sewage sludge (36% dry substance).

Fuel substitution calculation			
	Calorific value (kcal/kg)	Sub. factor CV coal	Sub. factor CV petcoke
Sewage sludge* 19 08 05	2940	2.07	2.79
Sewage sludge** 19 08 11	3408	1.79	2.41
Coal	6100	1	*
Petcoke	8200	*	1

		Plant 1			Plant 2		Plant 3	
	Unit	Without sewage sludge	MEKS	TKS	Without sewage sludge	TKS	Without sewage sludge	TKS
C_3S	%	70.3	61.5	62.7	72	70.8	67.7	60.4
C_2S	%	8.3	16.2	15.8	13.2	13.9	18.6	25.7
Compressive strength (28 days)	MPa	58.3	59.2	60.2	58.3	50.3	67.6	63.9
Compressive strength (90 days)	MPa	61.3	63.4	65.8	66.2	66.1	75	69.7

Above - Table 3: Results of sewage sludge usage in three German cement plants. (**Source**: German Cement Association: Research project No. 14884N.)

Dried sewage sludge with high organic content possesses a high calorific value. The table below shows an economic calculation of sewage sludge regarding the calorific value in comparison with pet coke and coal without any handling and operating costs and capital investment.

Waste coming out of sewage sludge treatment processes has a minor role as raw material substitute, due to their chemical composition.

Biomass - CO_2 value

The dried municipal sewage sludge has organic material content (ca. 40 – 45 wt %), therefore the use of this alternative fuel in clinker production will save fossil CO_2 emissions. According to the International Panel on Climate Change (IPCC) default of solid biomass fuel (Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. III) the dried sewage sludge CO_2 emission factor is 110kg of CO_2 per GJ without consideration of biogenic content.

Municipal sewage sludge is considered to be fully biogenic, hence the 'net' emission factor is zero (German Cement Association: *'Possibilities and limits of sewage sludge usage as secondary material in the cement industry.'* V. Hoenig). The usage of municipal sewage sludge as fuel supports the saving of fossil fuel emission. If the municipal sewage sludge is dried with usually unused waste heat the ecologic CO_2 balance of the sewage sludge can be taken fully into account.

Referring to the substitution calculation in Table 2, the usage of 2.54t dried sewage sludge saves 1t of coal which means savings of around 2.45t of fossil derived CO_2.

Influence on clinker quality

A research project of the German Cement Association [Research project No. 14884 N] describes the quality influence on clinker while using municipal sewage sludge. The substitution of 10% of the heat demand by sewage sludges (around 1 - 4t/h of dried sewage sludge, and around 8t/h of mechanically dewatered sewage sludge) showed that the content of alite slightly decreased and the belite slightly increased. The influences on 28 day compressive strength did not follow a common trend. While those compressive strengths from plant 1 increased with sewage sludge, it was quite the opposite at plants 2 and 3.

Due to the P content of municipal sewage sludges the influence on clinker can be significant. Experience that when the P level in clinker is > 0.8% setting times increase by approximately 20 to 30 minutes and one and two-day compressive strengths drop by around 10 - 15%. Investigations by S. Puntke show that the incorporation of P into C_3P-C_2S mixed clinker crystals decrease the C_3S content and increase the free lime. Up to 1% P in clinker no negative influence on laboratory cement behaviour was detectable.

The negative influences of P in cement are dependent on the individual clinker composition and should be monitored thoroughly.

Recommendations

Owing to the diverse origins of industrial wastewater, the sludge it produces has a wide range of dangerous substances with different compositions. To assess the environmental relevance of the sludge, each case must therefore be considered individually. The technical production aspects including procedures and materials used, the technical equipment and efficient working and operation of the wastewater treatment plant have to be considered carefully.

The composition of sewage sludge, among other things, is season dependent. In winter time, due to the high levels of de-icing salt used for road de-icing, the composition of sewage sludge varies. By and large the disposition of municipal sewage sludge in a cement kiln means that:

- Around 50% organic matter substitutes for the corresponding amount of fossil fuels,
- Around 50% inorganic matter substitutes for the natural raw materials,
- 100% of the sewage sludge is being disposed without production of any ashes or slags,
- The energy from organic matter is neutral in terms of CO_2 emissions.

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Below: Psyttalia Island Waste-water treatment plant, Greece.