Today's practice in stormwater management in Germany - Statistics

Données statistiques sur la gestion des rejets urbains par temps de pluie en Allemagne

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RESUME

Basé sur les dernières données disponibles en 2004 à l'Office Fédéral Allemand des Statistiques, cet article présente l'évolution, sur les dernières 35 années, des réseaux d'assainissement, des structures de traitement des eaux pluviales et du nombre de stations de traitement d'eaux usées en Allemagne. Les différents graphiques repris dans l'article montrent le degré de connexion de la population aux réseaux publiques d'assainissement, la longueur des réseaux par habitant, la répartition entre réseaux unitaires et séparatifs, le nombre et le volume global des bassins de rétention des eaux pluviales, le taux des eaux parasites dans les réseaux d'assainissement.

ABSTRACT

Based on the latest available data of the German Federal Statistical Office (Statistisches Bundesamt) of 2004, this paper presents the development of the sewer network, the number of wastewater treatment plants and the stormwater treatment and retention facilities during the past 35 years. The graphics show the degree of connection of population to a public sewerage, the length of sewers per capita, the spatial distribution of combined and separate sewer systems, the number and the overall volume of stormwater tanks and the rate and occurrence of sewer infiltration inflow.

KEYWORDS

CSO, history, sewerage systems, statistics, stormwater treatment, urban drainage.

1 INTRODUCTION

As a member of the European Community, Germany has to comply with EC standards. An essential act of legislation is the implementation of the EC directive 2000/60/EC (2000) and the transformation into national standards. This framework should establish an equally high water protection standard in all states of the EC. Anyhow, the sewer networks and the technical solutions applied may differ from one state to another. The present paper gives a statistical look on today's practice in stormwater treatment in Germany.

In Germany, legislation enforces the operators of sewer networks and treatment plants to supply data to the Statistical Offices of the 16 Federal Countries (Bundesländer), while a general statistics is prepared triennially by the Federal Statistical Office (Statistisches Bundesamt). The present paper is based on the latest available data from 2004, Destatis (2006), which are shown in Table 1 on the last page of this paper. In some cases, reference is made also to data from 1998, see Destatis (2001). The Federal Statistical Office publishes data only, no illustrations!

2 COMBINED AND SEPARATE SEWER SYSTEMS

The first sewer networks in Germany were built in the late 19th century. William Lindley and William Phillips Dunbar were two famous British engineers who designed the first combined sewer systems e.g. in Frankfurt and Hamburg. After the first mechanical sewage treatment plants came up, also separate drainage systems were built. The latter were preferred mainly in the North and the East of Germany, while the South is mainly governed by the combined system. Fig. 1 shows the up-to-date distribution.

However, there has been some shift in the past years. In general, there is a recent trend towards modified and separate sewer systems due to the present political preference. In federal countries with a low share of combined systems, nearly all new sewerage systems were designed as separate, and even some formerly combined systems got "re-separated". On the other hand, there are some countries in the South with a high share of combined systems where this trend is less pronounced. The "equator of combined systems", indicating an average of 50 % of the sewers being combined, has shifted southward in the past 12 years. However, note that there is a rather sudden change in the share of the system from the Northern and Eastern federal countries to the Southern and Western. Moreover, the cities of Berlin, Hamburg and Bremen resemble islands.

It is questionable whether this obvious split of the chosen drainage system is rationally determined. The 100-year-old argument that separate systems are advantageous in the lowlands is doubtful since some territories in the East are not less mountainous than in the South.

Furthermore, new investigations show that a separate sewer system not in every case will beat a combined one with respect to the impact on the receiving waters. The preference is strongly dependent on the kind of pollution parameter, see Weiss and Brombach (2004). A particular problem in separate systems are heavy metals in roof and road runoff. Keeping in mind also construction and operation costs, a well-designed combined system is still a good choice in the authors' opinion since the advantages of the separate system (including modified systems with infiltration of stormwater) are frequently over-estimated.

3 STORMWATER TREATMENT IN COMBINED SEWER SYSTEMS

German modern stormwater treatment in combined sewer systems dates back to the early seventies of the last century. Based on fundamental work of Krauth (1971), the construction of combined sewer overflow tanks (CSO tanks) in connection with biological wastewater treatment plants (WWTP) became common and was consequently adapted by the technical guideline ATV-A 128 (1977) of the Abwassertechnische Vereinigung (ATV), today DWA. At the end of 1987, an estimated number of 8 000 CSO tanks was in operation, cf. Brombach (1988). The Reunification of both former German states in 1990 disarranged any statistics due to the lack of data from the former German Democratic Republic. The first nationwide statistical overview was given by Brombach and Kuhn (1992), and official data were available from 1998 on.

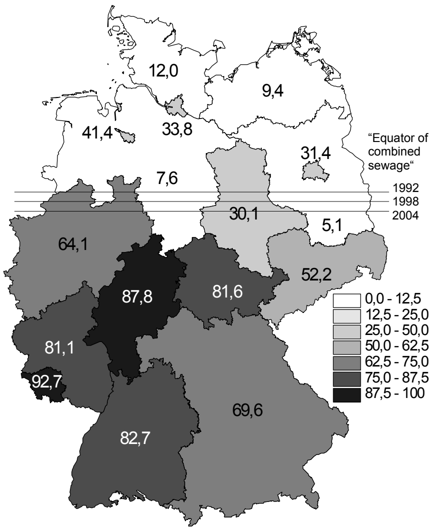

Fig. 1: Combined and separate sewer systems

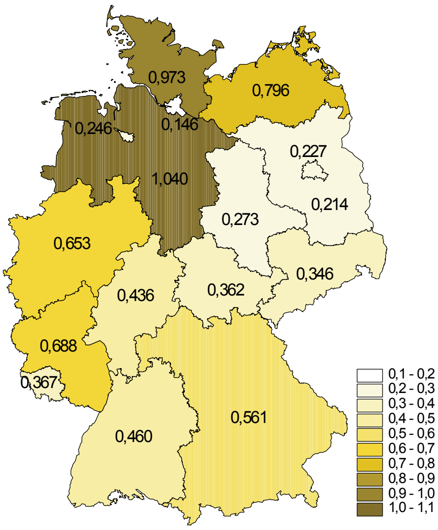

Fig. 2: Storage volume in stormwater tanks (separate and combined system) in m³/inh.

Stormwater tanks are decentral facilities for treatment of storm runoff in combined or in separate sewer systems. The terminology is defined in some DWA guidelines. However, the data from Destatis (2006) are more coarse and do not allow always sufficient differentiation of the types of stormwater tanks. Anyhow, the data indicate the actual number of structures and their total volume. In 2004, in total 41 569 stormwater tanks of all types were in operation in Germany. The total storage volume is 46 753 000 m³. This means an overall specific storage volume of 0.567 m³ per inhabitant. Fig. 2 shows the spatial distribution.

Itemized into tank types, 23 311 combined sewer overflow tanks are in operation, 15 408 stormwater retention basins and 2 592 settling tanks for treatment of stormwater in separate systems. In the average, every treatment plant has four satellite stormwater tanks.

Typical CSO technology in German combined sewer systems features one central or many decentral CSO tanks with a volume of 25 to 30 m³/ha of impervious surface. Every tank has a flow control which is limiting the flow to the WWTP to a share corresponding to the size of the catchment, typically to 2 to 4 times the peak dry weather flow. CSO tanks are dimensioned by technical rules such as ATV-A 128 (1992), today frequently using numerical quantity-quality simulation. Design handbooks such as ATV-DVWK-A 166 (1999) and ATV-DVWK- M 176 (2001) show good and proved designs.

4 POPULATION SERVED BY PUBLIC SEWERAGE

In the end of 2004, the population in Germany totalled 82.5 millions of inhabitants. With a total area of 356 954 km², the population density is 231 inh./km². For comparison, in the USA the mean density of population is merely 33 inh./km². Germany is a rather densely populated region which needs well developed drainage systems.

Around 95.5 % of the population is connected to a public-owned sewer system with a treatment plant. Even 14 years after the Reunification, some deficits can be seen in some Eastern federal countries. Anyhow, the biggest upgrading effort is made there, e.g. in the federal country of Brandenburg where the share of population served by a sewer increased from 68.6 % in 1998 to 82.6 % in 2004. Some federal countries such as Baden-Württemberg, Bremen, Hessen and Saarland, show a ratio of 99 % and even more.

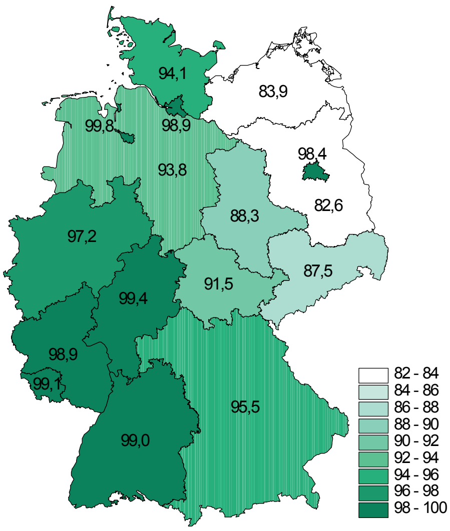

Fig. 3: Share of population served by a public sewer in %

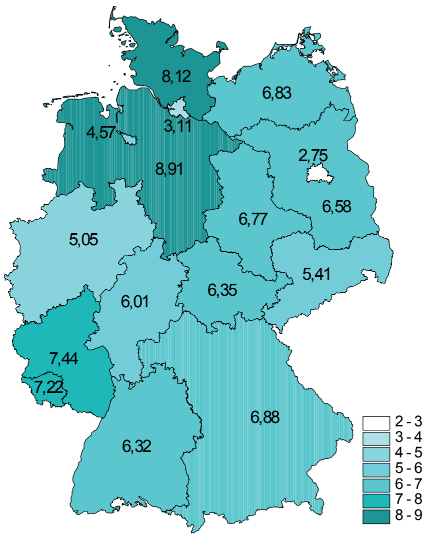

Fig. 4: Length of public sewers in m per inhabitant

5 LENGTH OF PUBLIC SEWERS

Another indicator on the urban drainage structure is the length of sewers. It totalled 514 884 km of public owned sanitary sewers, stormwater drains or combined sewers in the end of 2004. The sewer length showed an increase of 15.5 % since 1998, which is a gigantic investment in environmental protection, even if the public authorities are short in money. The typical sewer length per German inhabitant is 6.24 m. Since 1998, every citizen gained 0.80 m of sewer or 13 cm per year.

Fig. 4 shows that in big cities (such as the federal countries of Hamburg, Bremen and Berlin) the specific sewer length is much shorter, an economic advantage of the metropolis. Berlin has the shortest sewer system with a specific length off 2.75 m/inh. only. Niedersachsen with large rural areas and a particularly large share of the separate sewer system of 92.4 % has the longest sewers with 8.91 m/inh. Probably, this is also the most expensive drainage system per inhabitant in Germany.

A special development can be observed in some Eastern federal countries. The absolute length of sewers gained about 40 to 59 % since 1998. However, since the number if inhabitants decreased since 1990, the length per capita increased disproportionately high. In some cities which are affected particularly by migration, even demolition of some city quarters and modification of the sewer network is discussed.

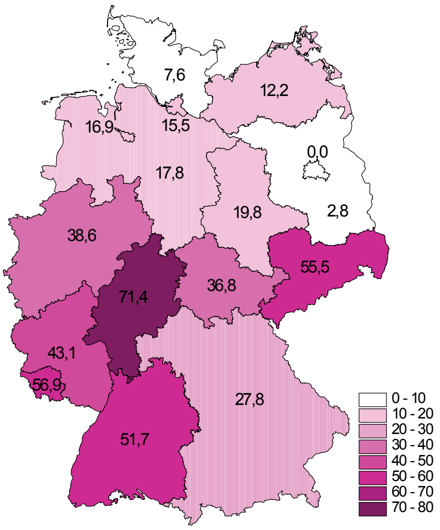

Fig. 5: Share of infiltration inflow (I/I) in % of the sanitary sewage flow

6 INFILTRATION AND INFLOW

Infiltration and inflow (I/I) is clean seepage entering the sewer by leakages and particularly by drainages of buildings. This sort of inflow is not desired, since it will leave a treatment plant with a higher pollutant concentration than it had when entering the sewer system. This will reduce drastically the efficiency of wastewater treatment. In the past few years, an increasing demand for I/I reduction grew up; nevertheless such measures are costly and hard to obtain properly.

In separate systems, also rainwater inflow in the sanitary sewer is regarded as I/I. Even if there might be some uncertainties caused by different methods for I/I determination applied in the Federal Countries, there is also a statistics in percent of the average sanitary sewage flow (Fig. 5). In the annual average, infiltration and inflow in Germany was 34.8 % of the sanitary sewage flow. The exception of 0 % I/I in Berlin is probably due to a lack of data.

7 DEVELOPMENT OF STORMWATER TREATMENT IN THE PAST

Fig. 6 shows the increase in number of stormwater treatment facilities from 1975 on. The data are taken from former publications of the authors, like Brombach (1979) and Brombach (1988). The following trends can be observed:

Wastewater treatment plants: The total number of WWTPs had grown to a maximum of 10 312 in 1998, but decreased since to 9 994 in 2004. In the average, 8 255 inhabitants are served by each WWTP. Small- to medium-sized plants obviously dominate. In the past few years, particularly outdated small installations were abandoned in increasing number and their sewer networks got connected to central new (or upgraded) WWTPs.

Stormwater tanks in combined systems (CSO tanks): In the end of 2004, the already mentioned number of 23 311 such structures had a total volume of 14 938 million m³. The average CSO tank size is 641 m³. The most rapid growth happened between 1987 and 1998, later the growth rate flattened. In relation to the citizens served by combined sewer systems, a specific storage volume of 311 litres/inhabitant is reached. Since most needed structures are already built, a stagnation in growth is plausible; moreover, economic recession enforces the communities to stretch investments over several years. On the other hand, the statistics does not show numerous upgrade projects of first-generation stormwater treatment structures built in the 1980's, made possible by modern flow controls and improved technical tank equipment like flushers, screens, etc., and also by progress in electronic devices, remote data acquisition and real-time control.

Stormwater retention basins in separate systems: A surprisingly high growth can be observed with stormwater basins and tanks in the separate system. Their total volume is 29 223 million m³, exceeding by far the storage volume in combined systems. Runoff retention is needed particularly for basement flooding protection and if the peak flow discharge in small receiving waters should be limited. The average structure size is three times as large as in the combined system, 1 900 m³.

Clarifier-type basins in separate systems: Treatment of surface runoff by sedimentation structures is used for motorways and other particularly polluted surfaces. The number of these structures also shows a distinct increase. Their average volume is 909 m³. The "dip" in the number in 1991 is probably due to data inconsistencies. Evidently, the frequently heard argument "no stormwater tanks are needed if a separate system is built" does not hold. In the past years, some technical rules were issued which support this trend, such as ATV-DVWK-M 153 (2000).

Combined sewer overflows (CSOs): In combined systems, traditionally overflow structures without significant storage volume are used. Anyhow, these do not appear in the statistics before 1998. Their number is also somewhat increasing. This is not quite plausible, since many new-constructed CSO tanks replace former CSOs. May be that not all such structures are yet included in the statistics.

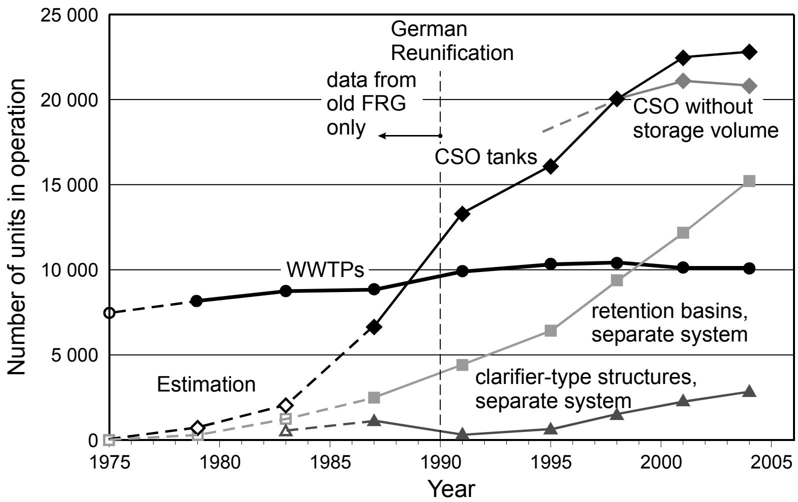

Fig. 6: Development of the number of stormwater treatment facilities with time

8 CONCLUSIONS

The present paper reflects the actual state of stormwater treatment in the public-owned sewer network in Germany. The latest census of the German Statistical

Federal Office dates back to 2004. Also, a look back on the development during the past 35 years is included.

After the German Reunification in 1990, big differences between both former German states were apparent particularly regarding the number of citizens serviced by a public sewer. These differences have been levelled since, but are still recognizable. Today, 95.5 % of the German population is connected to public sewerage. The number of treatment plants is close to 10 000. Small- and medium-size plants dominate.

Traditionally, in the Northern and Eastern federal countries, mainly separate sewer systems are used where in the South and West, combined systems prevail. In the past years, these differences have deepened. Modified and separate systems are preferred for new collecting systems, but to the authors' opinion more by political rather than by scientific arguments. The share of German citizens served by a combined sewer system diminished from 71.2 % in 1983 to 58.3 % in 2004.

Stormwater treatment has rapidly developed in the past 30 years. The number of structures in the combined system will gradually approach saturation. However, many first-generation structures are to be upgraded. In the separate system, the number of tanks is still increasing. New technical rules indicate that stormwater treatment and retention is also necessary in the separate sewer system. A total of 46 753 millions of m³ of storage volume – resembling 567 litres per inhabitant – is a proud number known from no other state the world.

Infiltration and inflow is a widespread problem regardless of the type of sewer system and should be tackled more intensely in the future.

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Statistical Property CSS: Combined Sewer System SSS: Separate Sewer System	inhabitants	population served by public sewerage	length of combined sewers, CSS	length of sanitary sewers, SSS	length of storm sewers, SSS	length of all sewers, CSS+SSS	sewer length per inhabitant, CSS+SSS	share of combined sewer system	number of CSO tanks, CSS	volume of CSO tanks, CSS	number of retention basins, CSS+SSS	volume of retention basins, CSS+SSS	number of clarifier-type tanks, SSS	volume of clarifier-type tanks, SSS	number of stormwater tanks of all kind, CSS+SSS	volume of stormwater tanks of all kind, CSS+SSS	stormwater tank volume per capita, CSS+SSS	number of CSOs without storage volume, CSS	number of wastewater treatment plants, CSS+SSS	average I/I flow, % of sanitary sewage, CSS+SSS
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Dimension	1000 inh.	%	km	km	km	km	m/inh.	%	n	1000 m^3	n	1000 m^3	n	1000 m^3	n	1000 m^3	m^3/inh.	n	n	%
Germany, federal country	82501	95.5	238201	170651	106032	514884	6.24	58.3	23311	14938	15408	29223	2850	2592	41569	46753	0.567	21454	9994	34.8
Baden-Wuerttemberg	10717	99.0	48931	10261	8534	67727	6.32	82.7	6612	3539	397	1271	254	123	7263	4934	0.460	3440	1118	51.7
Bayern	12444	95.5	52504	22925	10213	85642	6.88	69.6	6409	3184	2769	3353	598	442	9776	6979	0.561	4451	2633	27.8
Berlin	3388	98.4	1902	4154	3274	9330	2.75	31.4	13	46	101	700	11	23	125	769	0.227	531	1	0.0
Brandenburg	2568	82.6	677	12503	3716	16896	6.58	5.1	45	76	303	435	156	38	504	549	0.214	358	277	2.8
Bremen	663	99.8	809	1147	1072	3028	4.57	41.4	6	80	11	52	49	31	66	163	0.246	22	4	16.9
Hamburg	1735	98.9	1257	2464	1673	5394	3.11	33.8	12	103	11	59	29	91	52	253	0.146	196	1	15.5
Hessen	6098	99.4	28409	3948	4275	36631	6.01	87.8	2588	1697	781	896	43	68	3412	2661	0.436	3448	737	71.4
Mecklenburg-Vorpommern	1720	83.9	779	7528	3442	11750	6.83	9.4	81	160	453	1138	125	71	659	1368	0.769	205	525	12.2
Niedersachsen	8001	93.8	3451	41735	26095	71280	8.91	7.6	226	321	3068	7539	124	463	3418	8323	1.040	251	672	17.8
Nordrhein-Westfalen	18075	97.2	45181	25343	20786	91309	5.05	64.1	3348	3747	3303	7593	773	458	7424	11797	0.653	2037	695	38.6
Rheinland-Pfalz	4061	98.9	21462	4995	3754	30211	7.44	81.1	2338	1012	1131	1737	51	46	3520	2795	0.688	2663	777	43.1
Saarland	1056	99.1	6405	508	715	7628	7.22	92.7	460	243	92	94	21	51	573	387	0.367	1485	104	56.9
Sachsen	4296	87.5	9874	9036	4350	23260	5.41	52.2	429	251	749	1130	200	106	1378	1486	0.346	1263	791	55.5
Sachsen-Anhalt	2494	88.3	4179	9690	3016	16884	6.77	30.1	208	125	373	509	30	47	611	682	0.273	291	280	19.8
Schleswig-Holstein	2829	94.1	1635	11994	9330	22960	8.12	12.0	64	70	1409	2171	351	513	1824	2754	0.973	300	824	7.6
Thueringen	2355	91.5	10746	2421	1787	14954	6.35	81.6	472	285	457	547	35	21	964	853	0.362	513	555	36.8

Table 1: Compilation of raw data from Destatis (2006) on which the graphics of the present paper are based upon