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RESEARCH ARTICLE

STUDY ON ECONOMIC SUSTAINABILITY OF SEWAGE SLUDGE TREATMENT PLANTS IN CHINA AND FINLAND.

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Abstract

Arising metropolitans, industrialization and urbanization caused urgency to solve the sludge problem appropriately in the world, especially in developing countries such as China; sewage sludge treatment technology and site selection is crucial for cost reduction; the objective of the research is to investigate the economic sustainability of Shanghai Bailonggang sewage sludge Treatment Plant and the newly constructed sewage sludge treatment plant in Changsha. The economic sustainability of a wastewater treatment plant in Helsinki, Finland is discussed as well in this paper as a contrast subject. The results have showed that increased economic burden and growth of plants globally increased amount of sludge that affected sludge treatment location scarcity to energy intensive transportation methods issuinganaerobic digestion to be vital in wastewater treatment plant to utilize energy recovery. Viikinmäki has 25 341MWh energy recovery which has officially reported to covers 60% of plant's needsand heat recovery by engines with AD are altogether 8 922MWh (100%) which is total wastewater treatment plants heat using capacity.

Introduction:-

High rising of demand for clean water is becoming a more serious issue all over the world. Currently large scale urbanization is carrying on in China. Increasingly, more wastewater is produced; besides, water quality has deteriorated significantly over the last few decades. All these urge the municipal governments to solve wastewater and sewage sludge problem. In metropolitan cities like Shanghai some old wastewater treatment plants located at city center may have to be torn down, wastewater and sewage sludge are transported to suburb areas for treatment and disposal. The city growth and urbanization have placed a critical burden to Shanghai with sanitation and wastewater treatment. Water and power supply requirements **(Fig 1.)** have increased within 50 years massively by 32 million cubic meters of water and 1300 million kWh. Discharge of wastewater has increased annual rate of 67.7 million tons **(Cui & Shi, 2012)**. All happens due to land constraint in downtown areas. As a result, super-long pipelines and powerful pump stations have to be constructed for transportation of megatons of sewage sludge from downtown to suburb areas. Within Chinese studies economics is the most important criterion in decision making and it's the most common in developing countries when considering wastewater or sludge treatment plants **(Massoud, Tarhini, & Nasr, 2009)**. Commonly used indicators were globally cost of operation, technology, maintenance or

replacement **(Annelies J. Balkema a, 2002)**. The strongest factor to technology selection has been cost, which reflected to sludge treatment in China by less interests about AD. Currently only 50 Chinese WWTP's, that is less than 5% of Chinese sewage treatment plants, used anaerobic digestion in the wastewater and sludge treatment process. Anaerobic digestion has been reported to be the lowest environmental and economic burden by significant sludge reduction in volume, thus it decreased further sludge, recovered energy, however required expensive treatment preparations **(Xu, Chen, & Hong, 2014)**.

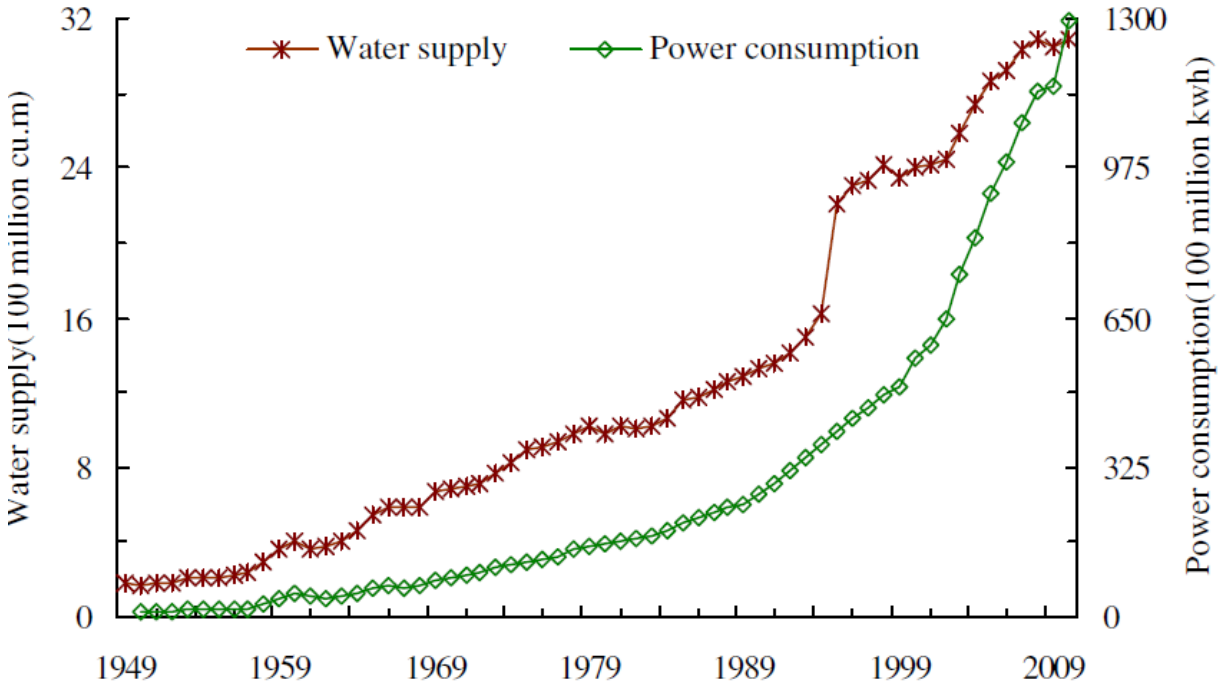

Figure 1:- Water supply increase and power consumption in shanghai from 1949 until 2009 **(Cui & Shi, 2012)**

Bailonggang WWTP, which is the largest WWTPs in Asia, and oneof the largest WWTPs in the world is located inShanghai and has a capacity of 2,000,000 m^3/d. Initially this WWTPused chemically enhanced primary treatment (CEPT) as its technology, but it has been upgraded to a secondary treatment plant. The major technology used in this WWTP is the multi-modeA^2/O (anaerobic/anoxic/oxic) process, which is characterized byits flexibility to switch and optimize flowrates of mixed liquidand returned sludge. A two-stage centrifugation process is used for sludge thickening and the sludge is dewatered to water content below 80%. In the advanced sludge dewatering process, the dewatered sludge of Bailonggang WWTP and the three adjacent WWTPs are combined and mixed with gravity-thickened sludge to reach water content of 93%, then conditioned by CaO (20%) and $FeCl_3$ (8%), and then pressed to reach water content below 60% by filter press. Daily sludge amount being treated: 204 tDS/d (design parameter), sludge quantity: 4080 m^3/d (with MC of 80%, design parameter), 156.3 ±23.8 tDS/d (operating parameter), daily produced methane gas: 44512 m^3/d (design parameter), 16503 m^3/d (operating parameter), average yearly gas production: 10.73 m^3/m^3 sludge with MC of 80%, methane gas yield: 0.82 m^3/kg VSS, average daily gas consumption: 21106 m^3/d. **(Ren et al., 2015)**.

In contrast, the newly built sewage sludge treatment plant in Changsha suburb area receives 500 tons a day of dewatered sewage sludge with MC (moisture content) of 80% from all WWTPs located in Changsha City. The dewatered sludge is transported to this newly built plant by trucks. Then it is diluted to 86% MC with clean water. Afterwards, it enters the reactor for thermal hydrolysis. Thermal hydrolysis is a two-stage process combining high-pressure boiling of waste or sludge followed by a rapid decompression. This combined action sterilizes the sludge and makes it more biodegradable, which improves digestion performance. Thermal hydrolysis can quickly realize the reduction of sludge. The thermal hydrolysis of dewatered sludge is realized by steam injection at a temperature of 170°C for 30 minutes. The HAD of hydrolyzed sludge is done within a HRT (hydraulic retention time) of 15 days and reaches volatile reduction of more than 40% on dewatered biological sludge. The digested sludge is further

dehydrated to MC of 60% and further heated to MC of 40%, which can be applied as landfill cover soil material.**(Liu Xiao Jun, 2015)**.

Current situation in Finland of sludge treatment has harnessed AD reaching over 50% in WWTP's that is used mostly in the largest treatment plants. The main and largest WWTP's in Helsinki region, Viikinmäki has treatment plant size of 278 011 m^3/day including Suomenoja 100 191 m^3/day, those treat wastewater in Helsinki, Espoo and Vantaa area. Viikinmäki sludge pre-treatment's primary sedimentation tank pumps around 3.4% DS (dry solids) sludge to 4x10,000m^3 anaerobic chambers with temperature of 36-37˚C for 14-20 days total by daily 2,400m^3 flow rate. AD's gas is collected to 4x2,500m^3 chambers to stay for 3-4 days **(HSY, 2013)**, meanwhile sludge processed to temporary storage until dried by 4x160kW powerful, 1,700l centrifuges. These centrifuges have rated input flow of 67m^3/h, 2,0tTS/h, those spend polyelectrolyte 100t annually performing 28% DS, which equals 60 000t of dry sludge **(Mari Heinonen, 2016)**.Treatment methods of average Finnish sludge treatment are presented in table 1. eleven questionnaire treatment plants are displayed in table 2. revealing distances of sludge transportation treatment. An estimated optimal sludge content in Finnish wastewater sludge has an average of 20% DS, which equals 80% MC (moisture content) represented in Chinese data.

Methods and Techniques:-

Sludge treatment in Finland is regularly based on following the favorable treatment as following Table 1 and 2; composting (529 RMB/t), digestion with composting (483 RMB/t), thermal drying (791 RMB/t), themophilic digestion (385 RMB/t), incineration (676 RMB/t), kemicond (368RMB/t) and lime stabilization (245 RMB/t). Kemicond process is thickening or digestion, sludge conditioning with H_2O_2 and H_2SO_4, processed with NaOH and polymers to drying by helix vise, centrifuge, beltpress or chamber press. Lime stabilization utilizes burnt CaO to react with sludge reaching pH level of 12, halting biological activity and sanitizing sludge in 60°C. Kemicond and lime stabilization won't release any useful energy, composing them inefficient practices in Finland. Incineration is generally avoided, nonetheless used in conditions without proper treatment preparations. Thermophilic digestion is less likely used and commonly it has 0, 20, 40% replaced by food industry slurry. Commonly digestion in Finland had been used in half of the plants according to a table 2. however it has a secondary sludge composting possibility or thermal drying, that can utilize heat produced from biogas. Alternative heat sources respectively as follows external steam (489 RMB/t), external biogas (431 RMB/t) for thermal drying. Composting seen in table 2. is used almost always as an end product that doesn't depend on size or distance of the treatment plants **(Pöyry Environment Oy, 2007)**. It is considered to be environmentally sustainable technology, however economic sustainability is to reproduce useful material from sludge, which is not considered in this treatment cost of composting.

Table 1:- Finnish methods for sludge treatment 80% DS.**(Pöyry Environment Oy, 2007), (Elina Lohiniva, 2001)**

Sewage sludge treatment technology	**Operation investment (€/t)**	**Operating investment (RMB/t)**
Gravity concentration	40	280
Anaerobic digestion	44-94	217 - 553
Dehydration	60	420
Heat drying	63-163	791
Heat hydrolysis	70-123	675
Kemicond	39-66	368
Lime stabilization	30-40	245
Sewage sludge disposal technology		**Operating investment (RMB/t)**
Landfilling	0-132	0-924
Land use	92-110	644-770
Composting	71-80	529

Table 2:- Finnish WWTP sludge questionnaire in 2009 **(Tukiainen, 2009)**

Plant number	Distance to next treatment	Unit	Sludge amount tons per year	DS %	Sludge pre treatment	Sludge after treatment
1	7	km	967	20,0 %	Centrifuge	Compost, Dumb waste
2	60	km	200	24,0 %	Thickening, Centrifuge	Compost
3	10	km	2559	24,0 %	Centrifuge	Compost
4	6	km	4800	15,0 %	Thickening, Shaftless Helix Vise	Compost
5	0	km	4900	26,0 %	Thickening, Digestion, Centrifuge	Compost
6	12,5	km	13237	17,0 %	Thickening, Centrifuge	Digest
7	16	km	9970	22,4 %	Thickening, Centrifuge	Compost
8	0,2	km	6559	30,0 %	Thickening, Digestion, Centrifuge	Compost
9	0	km	30000	22,0 %	Centrifuge	Compost, Chemical Kemicond
10	40	km	19279	31,0 %	Thickening, Digestion, Centrifuge	Compost, Digest, Dumb waste
11	40	km	60500	30,0 %	Digestion, Centrifuge	Compost

Chinese WWTP have estimated from five options: 1.Anaerobic digestion with land application, 2.Composting with land application, 3 Lime stabilization with land application, 4.Lime stabilization and landfill, 5.Incineration with landfill to apply. From those choices the most environmental friendly method was chosen to be 1.Anaerobic digestion with land application **(Xu et al., 2014)**. Sludge treatment in China is approximately based on 71.5%, 40.6%, 38%, 5% and 3.5% by using thickening, dewatering, dewatering, drying, anaerobic digestion and composting. End of life treatment process agricultural use 45%, landfill 31% and incineration 3,5% **(Xu et al., 2014)**. Sludge in agricultural use contains a wide diversity of pathogens, therefore its use could be banned or restricted **(Gianico, Braguglia, Cesarini, & Mininni, 2013)**. Two of the most powerful economic outcomes are disposal of sludge and income acquired from electricity sold **(Tomei et al., 2016)** ,noticing cost cannot exceed the benefits (Annelies J. Balkema a, 2002). Noticed 50 WWTPs (5%) in China have AD struggle with stable operation and investment costs compared with non-AD WWTPs. Those payoffs of biogas production from Chinese sludge in AD doesn't have specific conditions to economic benefits which influences to site selection and technical schemes. **(Zhou, Barjenbruch, Kabbe, Inial, & Remy, 2016)**. In the following table 3. gravity concentration, anaerobic digestion, landfilling and land use operation investments approximately follow 20RMB/t, 38 RMB/t, 75RMB/t and 42RMB/t. The cost of capital investment gives a direction of using sludge treatment by favoring cheaper options and economic stability.

Table 3:- Chinese sewage sludge operation and capital investment of Changsha sludge treatment when moisture content reaches 95%. **(Liu Xiao Jun, 2015)**

Sewage sludge treatment technology	**Capital investment ($\times 10^4$ RMB/t·d)**	**Operating investment (RMB/t)**
Gravity concentration	4.5	20
Anaerobic digestion	27	38
Dehydration	14	30
Heat drying	35	175
Heat hydrolysis	2	50
Sewage sludge disposal technology	**Capital investment ($\times 10^3$ RMB/t·d)**	**Operating investment (RMB/t)**
Landfilling	125	75
Land use	0	42

Table 4:- Chinese sewage sludge operation and capital investment of Bailonggangsludge treatment when moisture content reaches 80%. **(Liu Xiao Jun, 2015)**

Sewage sludge treatment technology	**Capital investment ($\times 10^4$ RMB/t·d)**	**Operating investment (RMB/t)**
Gravity concentration	18	80
Anaerobic digestion	72	152
Dehydration	56	120
Heat drying	140	700
Heat hydrolysis	8	200
Sewage sludge disposal technology	**Capital investment ($\times 10^3$ RMB/t·d)**	**Operating investment (RMB/t)**
Landfilling	500	300
Land use	0	168

Techniques:-

Continuous process of sludge treatment calculates operation cost by following table 4. and equation of continuous process TR, where beltpress has 500 tons/d sludge treated with moisture content of 0.99 by operation cost of 20 RMB/t that represents daily operation cost of 3,333 RMB*10^3/t. Following **Fig: 2, 3, 4, 5, 6** are using by same replicated equation. In this replicated model sludge cost depends on moisture content of previous treatment followed to the next treatment, which considers before treatment amount of sludge with process cost from table 3 in China and table 1 in Finland by noticing the MC and starting amount of sludge.

Continuous process of sludge treatment TR= $S_0 * TrC * MC_{-1}$

Where,

TR represents calculated sludge treatment operation cost or calculated capital investment S_0 represents treatment of sludge per day

TrC represents treatment unit cost for operation or treatment unit cost of capital investment

MC_{-1} represents moisture before current treatment

Table 5:- Data provided for TR calculation to Changsha, Bailonggang and Viikinmäki. **(Liu Xiao Jun, 2015), (Tukiainen, 2009), (Pöyry Environment Oy, 2007)**

Changsha process	MC (%)		Bailonggang process	MC (%)		Viikinmäki process	MC (%)
Start	0,99		Start	0,99		Start	0,99
Beltpress	0,8		Anaerobic-anoxic-aerobic	0,99		Sedimentation	0,964
transportation	0,8		Centrifuge two stage 1	0,8		Anaerobic Chamber 1	0,85
Dilution	0,86		Centrifuge two stage 2	0,8		Anaerobic Chamber 2	0,85
Thermal hydrolysis	0,91		Thickening	0,8		Anaerobic Chamber 3	0,85
AD	0,4		Gravity thickening	0,93		Anaerobic Chamber 4	0,85
Dehydration	0,6		Conditioning	0,93		Centrifuge 1	0,72
Heat drying	0,4		Filter press	0,6		Centrifuge 2	0,72
landfilling	0,4		Landfill	0,6		Centrifuge 3	0,72
						Centrifuge 4	0,72
						Composting	0,6

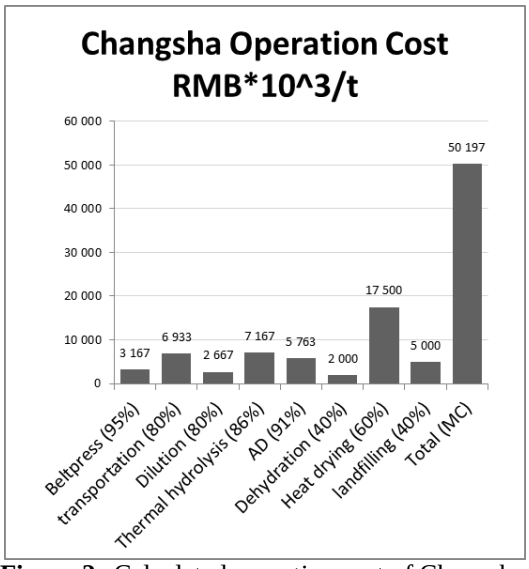

Figure 2:-Calculated operation cost of Changsha

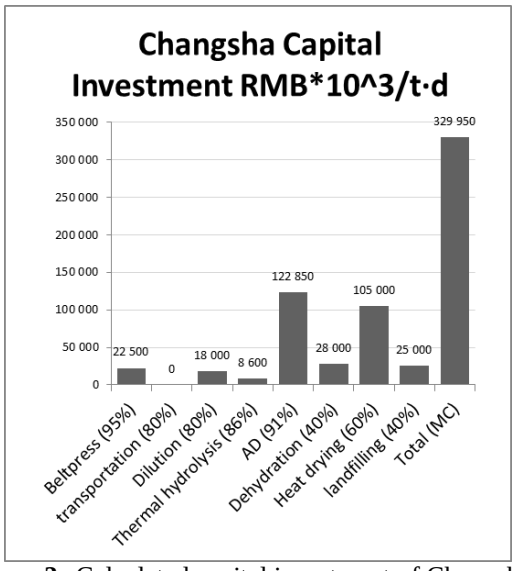

Figure 3:-Calculated capital investment of Changsha

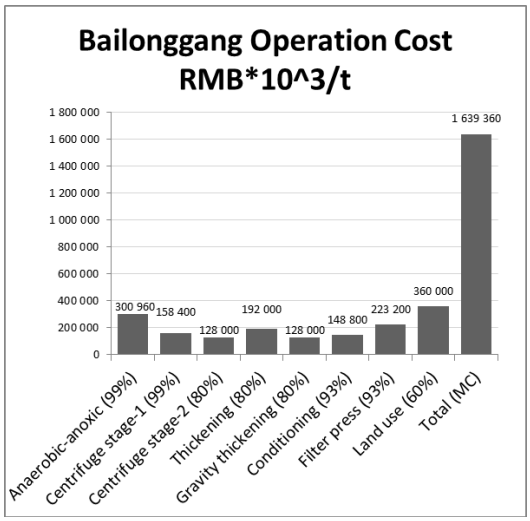

Figure 4:- Calculated operation cost of Bailonggang.

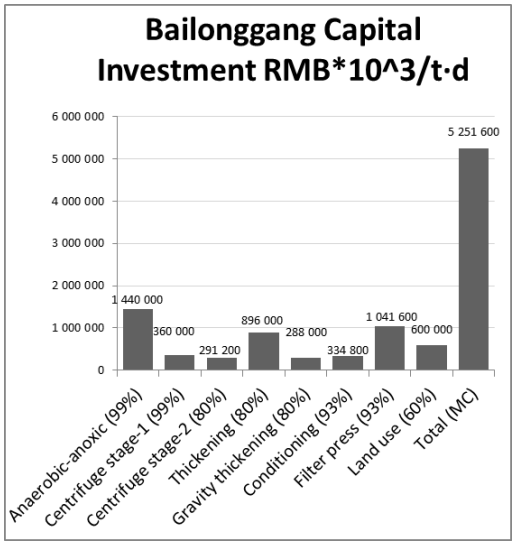

Figure 5:- Calculated capital investment of Bailonggang.

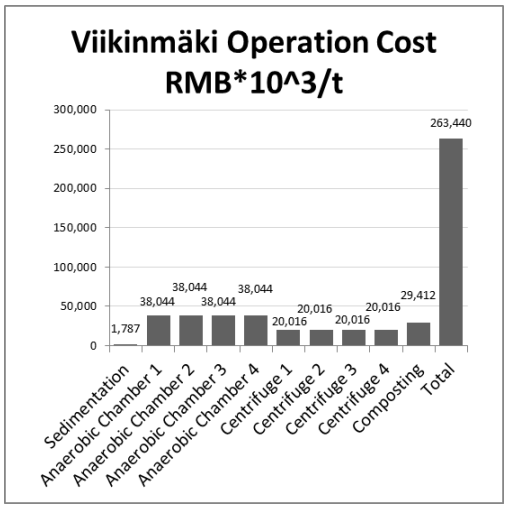

Figure 6:- Calculated operation cost of Viikinmäki.

Result and Discussion:-

The average Chinese WWTP final disposal includes thickening, conditioning, dewatering, stabilization and drying **(Yang, Zhang, & Wang, 2015)**. As seen in **Fig 2.** Changsha operation cost is relatively high in heat drying and transportation. AD in **Fig 2-6** have operation costs of Viikinmäki (38,044 RMB*10^3/t) and Changsha (5,763 RMB*10^3) those represented a significant cost difference and treatment efficiency of AD in Viikinmäki by 4 digesters. Anaerobic digestion (270 x 10^3 RMB/t·d) has higher capital investment than heat drying (350 x 10^3 RMB/t·d) in **Fig 3**, however heat drying can be energy demanding which can be seen in **Fig 2**. Changsha's operation costs (17,500 x 10^3 RMB/t) results. Viikinmäki's AD (38,044 x 10^3 RMB/t) is comparatively higher to Changsha AD (5,763 x 10^3 RMB/t), but Changsha capital investment in **Fig 3**. has fluctuation by high cost peak in AD (122,850RMB*10^3) and heat drying (105,000RMB*10^3), when compared to **Fig 5**. Bailonggang's, that has more stable capital investment. Changsha **Fig 2**. and**3**. lead to a result of inefficient technical schemes, where transportation, AD and heat drying have the fluctuation higher in operation cost and capital investment. **Fig 4**. Bailonggang, **Fig 6**. Viikinmäki had more stable treatment costs and **Fig 5**. Bailonggang capital investment had more stabilized investments in treatment of sludge in comparison of Changsha. Those differences between Changsha, Bailonggang and Viikinmäki implicated financial shortage affected technical schemes of Changsha in constraint of the space, thus price of land raised higher and transportation became an issue. Transportation of wastewater or sludge is necessary in larger cities due to price of land constraint, when populations in cities grows bigger **(Cui & Shi, 2012)**. "In the future centralized approaches are non-sustainable with high investment and require maintenance and update, which is burden for location selecting **(Ma, Xue, González-Mejía, Garland, & Cashdollar, 2015)"**.Location selection and Lifetime had common prediction to whole collection systems or of parts of WWTP's had to be renewed every 50-60 years, besides the long lifetime WWTP's required many periodic of maintenances, that can be seen in electricity and heating low values in **Table 6**. and**7**.during June, July and August. **(Libralato, Volpi Ghirardini, & Avezzu, 2012)**

Table 6:-Viikinmäki biogas electricity production from sludge in 2015.**(Johanna Castrén, 2016).**

Month	Bought, MWh	Produced MWh	Used in Process MWh	Total consumption MWh
January	1 278	2 169	3 030	3 447
February	1 083	2 086	2 810	3 169
March	1 195	2 295	3 116	3 490
April	952	2 283	2 872	3 235
May	798	2 484	2 890	3 282
June	793	2 378	2 786	3 171
July	794	2 354	2 748	3 148
August	2 572	667	2 888	3 239
September	1 093	2 140	2 864	3 233
October	1 040	2 286	2 933	3 326
November	1 291	2 033	2 941	3 324
December	1 356	2 166	3 146	3 522
Total	14 245	25 341	35 024	39 586

Table 7:-Viikinmäki Heat production by engines, boilers, HRV "Heat recovery ventilation", AD and sold to customers 2 601MWh annually.**(Johanna Castrén, 2016).**

Month	Produced by Engines MWh	Produced by Boilers MWh	Produced in HRV or MVHR MWh	Sold to Customers MWh
January	1 790	1 194	1 059	312
February	1 817	750	965	204
March	1 976	726	996	188
April	1 968	588	827	297
May	2 109	376	758	206
June	1 998	74	633	149
July	1 799	103	321	116
August	519	1 328	460	100
September	1 716	413	418	140
October	1 973	344	764	233
November	1 752	653	736	289
December	1 925	739	985	367
Total	21 342	7 288	8 922	2 601

Sludge treatment coordination and location selection is critical for future demands, Changsha contractors can momentarily bring a lot of sludge in which case all the sludge cannot be immediately dealt within, the storage space can end and feeding material can also become a shortage. Coordinating of sludge will also take into account the introduction of different stages and schemes of sludge to treatment plants. For example in Finland composting plant is imported from different sources, treated at the same time very wet sludge, requiring supporting material and promoting very wet and dried sludge at the same time for treatment **(Tukiainen, 2009)**. **Table 2** illustrates Finnish wastewater treatment plants sludge transportation distances, those lead to a fact treatment plants are in urban or semi distances to next treatment, whereas composting is chosen to be the most common treatment method within nearby location**(Hong, Hong, Otaki, & Jolliet, 2009)**. Sludge treatment centralized approaches are non-sustainable with high investment, difficult maintenance and upkeep, including WWTP location selection by land scarcity**(Ma et al., 2015)**.Decentralized approaches are more flexible, however transportation is typically in China 50-80km to be equivalent of 0,65RMB/km, respectively 52rmb of maximum transportation cost for 80km **(Liu Xiao Jun, 2015)**. Affordable transportation distances in Finland for AD sludge and agricultural sludge are 25km's, industrial and municipal sludge distances can be 150-250km's at maximum. **Table 2**. sludge treatment questionnaire of schemes follow commonly at site of WWTP or nearby location between 0-15km's, estimated 20% transports sludge outside of WWTP over 15km's. Treated sludge end product as composting 0-15km's, over 15km's and external party represent 50%, 20%, 30%. In any huge scale industrial plant's sludge is worth pre-dry thermally, whether alternative option is to suburb area incineration, transportation of sludge becomes non-profitable between 50-100km distances or more.

The main transportation method from centralized plant to urban is pumping sludge, which is responsible for about 20 percent of the world's electricity consumption. **(Tukiainen, 2009)** Helsinki suburb area has over 500 wastewater pumping stations, 30 pumping stations located above ground and rest located underground. Pumping is an electricity consumer, used in many industrial processes and the highest electricity required process. Reduction in the amount of sludge can be clearly seen in handling costs and environmental impact, although reducing the length of the pipeline is a principle solution to minimize pumping energy consumption.

Thermal dryers in plants consume a lot of energy, this can make a fully dried sludge (>85% TS) to incineration process a possible solution as sludge disposal. Under 45% TS causes commonly a dust problem, this is for centralized plants a critical decision of sludge to pump suburbs. Transported sludge with lime stabilization increases amount of sludge. Whether quantity grows larger, preparations of ammonia recovery are necessities. Some sludge disposals in forms of incineration require large scale preparations to establish facility in any residential neighborhood and affects residents by environmental concerns **(Eggimann, Truffer, & Maurer, 2015)**. Focusing of the pumping process is the most efficient and common way to transport sludge from place A to B. Energy intensive pumping has a side-effect, "centralized plants returning recycled water can require tremendous energy due to pumping"**(Naik & Stenstrom, 2016)**. Pumping focuses an importance to reduce the consumption of electricity, which can be costly in certain situations. The two considerations those have the greatest impact on the final economic outcome are sludge disposal cost and income deriving from electric energy sale. In average 75% of wastewater capital needs are for pipe repair **(Ma et al., 2015)** however electricity use accounts for approximately 80% of drinking water treatment distribution cost and 25%–40% of the operating budgets for wastewater facilities. Urbanization, land scarcity, cities growing bigger, the longer the distances to transport water and the higher the energy demand becomes**(Ma et al., 2015)**.

There is a strong dependency on electrical energy supply, total investments in China have increased by 99.08% and 2.78 times nearly in ten years **(Zhang et al., 2015)**. Scheme of a typical Chinese WWTP uses 60% of energy in water treatment, those 40% left are for sludge treatment. **(Liu Xiao Jun, 2015)**. **Table 6** and **7** indicate produced electricity and heat of Viikinmäki, which officially can cover 60% of electricity in whole wastewater treatment process and 100% of heat consumption that is officially announced by Viikinmäki. Provided data in wastewater and sludge process is 25341MWh/ 35 024MWh = 72% percentage of electricity in this WWTP process according to data in **table 6,** which is revealed to be 60% by Viikinmäki WWTP.AD-model from Viikinmäki's 60% recovering would cover the scheme of typical Chinese WWTP's scheme or alternatively sludge treatment with 20% energy leftover to be used for example in pumping process. Energy as resource to trade cost or buyback in operation process represents a huge possibilities whether treatment plants last longer than pipe-chain of life.Nowadays the in-plant pumping and aeration in common primary and secondary treatment often consists of more than 60% of the total plant electricity use. The further sludge treatment and disposal is also energy-intensive because of dewatering. Viikinmäki's biogas electricity production line in **table 6**. focuses AD into 4 digestion chambers. Chambers pay-off (25 341MWh) of the

energy produced in whole wastewater treatment process, rest of the energy is bought from local district electricity (14 245MWh). Comparing the overall production of biogas to overall consumption of electricity in treatment plant can utilize around 72% of electricity **(Johanna Castrén, 2016)**. Total consumption of WWTP is (39 586MWh), which uses (35 024MWh) in main process. Leftover electricity is counted as in maintenance, backup electricity or used in service tasks. Energy loss in this situation can be estimated as building heating or upkeep of the control service systems.

Conclusion:-

China favors low cost medium efficiency treatment methods, whereas AD is useful in the future for large scale and medium scales WWTP's. Anaerobic digestion investment in China is expensive according **table 3** and **4**, moreover it's more expensive in Helsinki Viikinmäki with energy recovery by 60% announced officially by Viikinmäki that is 39 586MWh of electricity and heat recovery measured in 2015 by 40 153MWh annually, which covers 100% heating process in total wastewater plants usage. Digestion cost of sludge treatment is generally more expensive in Finland compared to Changsha or Bailonggang and more efficient, when moisture content is considered to be equally same in Viikinneva, Bailonggang and Changsha. However large investments and controlled anaerobic digestion process have huge benefits in sludge treatment process for energy recovery and controlling operation cost. Investing incineration or AD to nearby WWTP commits a possibility to utilize energy recovery that can reduce burden of transportation or sludge volume reduction. Transportation of sludge by trucks is causing extra costs in Changsha that can be avoided by structuring nearby sludge treatment plant considering example of Viikinmäki WWTP, which has over 500 wastewater pumping stations. After all growing cities and treatment plants of Bailonggang and Changsha will face land scarcity in the future, which would need preparations to relocate treatment plants to suburb areas.**(van Afferden, Cardona, Lee, Subah, & Muller, 2015)**Technical schemes in the two Chinese WWTPs might not be reasonable enough from the energy recovery and economic perspective, but for today's China, those combinations of technologies may be the only reasonable way to solve the sewage sludge problem without scars due to financial shortage, constraint in the space of the existing WWTPs, sky-high land price and land scarcity in Chinese metropolitan areas.

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