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Prerequisites for Public Acceptance of Waste-to-Energy Plants: Evidence from Germany and Indonesia

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Abstract

Construction of waste incinerators often encounters resistance from the public. The minimum requirements for the acceptance of these installations include modern air pollution control (APC) technology and safe disposal of residues. Confidence in the statements of government and government agencies as well as on those who support is an important point of acceptance. Independent scientific bodies such as universities can help to make this happen. In the case of the installation of waste into energy (WtE), such scientific support can be the measurement of emissions and their evaluation. Many products that enter the waste stream contain heavy metals, persistent organic pollutants, and other harmful substances. Their presence constitutes another challenge for recycling. This challenge can be solved most likely by binding specifications for chemicals in and design for recycling of products.

Abstrak

Studi Penerimaan Publik pada Pabrik Energi Sampah: Fakta dari Jerman dan Indonesia. Pembangunan insinerator sampah sering mengalami penolakan dari masyarakat. Persyaratan minimum agar instalasi insinerator dapat diterima adalah adanya teknologi pengendalian pencemaran udara modern dan pembuangan residu yang aman. Kepercayaan pada pemerintah dan lembaga pemerintah serta mereka yang mendukung program ini merupakan hal yang penting agar bisa diterima di masyarakat. Institusi independen seperti Universitas dapat membantu mewujudkan hal tersebut. Dalam kasus instalasi limbah menjadi energi (WtE), dukungan ilmiah bisa berupa pengukuran emisi buang beserta hasil evaluasinya. Banyak produk yang masuk ke aliran limbah mengandung logam berat, polutan organik yang persisten (POPs) dan zat berbahaya lainnya. Kandungan bahan berbahaya tersebut menjadi tantangan tersendiri dalam proses daur ulang. Tantangan dalam permasalahan ini dapat diatasi dengan cara mengikatkan bahan kimia di dalam spesifikasi tertentu dan merancang daur ulang produk.

Keywords: acceptance, air pollution control, heavy metals, persistent organic pollutants (POPs), waste-to-energy

1. Introduction

The Global Waste Management Outlook (GWMO) 2015 of the United Nations Environment Programme UNEP and the International Solid Waste Association ISWA [1] has set five goals: by 2020, ensure universal access to adequate, safe, affordable solid waste collection (W1); eliminate uncontrolled dumping and open burning (W2); by 2030, ensure the sustainable and environmentally sound management of all wastes, particularly hazardous wastes (W3); substantially reduce waste generation through prevention and the three Rs (3Rs) (reduce, reuse, and recycle) and thereby create green jobs (W4); halve global per-capita retail and consumer food waste and reduce food losses in the supply chain (W5).

Midterm goals (2030) include altering people’s awareness to avoid wastes and to inculcate the 3Rs in their habits. This change entails a lengthy process. More environmentally sound technologies may reduce the demand for thermal treatment of wastes in the interim, but they do not solve the problem of dealing with hygienically problematic wastes (e.g. hospital wastes), or hazardous heavy metals (mercury, cadmium) and persistent organic pollutants (POPs) (e.g. polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers

(PBDPE), perfluorooctanesulfonate (PFOS), and pesticides) in products or waste streams (e.g. wastes from electrical and electronic equipment (WEEE), accumulators, and batteries). So, long as separate collection, treatment, and disposal of wastes containing hazardous substances (pesticide containers, medical waste) are not widespread, mechanical-biological treatment (MBT), composting, or sanitary landfills merely relocate the problem.

Recycling also faces the problem of hazardous chemicals in products. Although thermal treatment is presently a subordinate option in the waste management hierarchy, it is a building block for problem solving. Therefore, it is not surprising that projects like municipal solid waste incinerators (MSWIs) combined with energy recovery (waste-to-energy, WtE), MBT, or solid recovered fuel production plants are in the stage of planning or realization in Asia.

Unfortunately, these projects are often poorly received. Irrespective of the technologies used, communities fear the release of pollutants. The Government of Indonesia, for example, was urged in 2017 to cease building WtE plants in seven cities after the Supreme Court ruled waste incineration illegal because the emission of hazardous dioxins, furans, and heavy metals threatened the environment and people's health [2]. Recycling also faces the problem of heavy metals and POPs in old products and waste streams. Facilities that are not state-of-the-art for recycling WEEE are the reason for some of the world's most polluted places.

2. Methods

This study analyzes problems with the acceptance of waste treatment plants in Germany and the solutions proposed or enacted.

Waste incineration in Germany has long been controversial, mainly because of emissions. Requirements limiting the emission for waste incinerators were set in the 17th Ordinance under the Federal Emission Control Law (17th BImSchV) adopted in 1991, revised in 2003, and amended in 2013 by the European Industrial Emissions Directive 2010/75/EU. Table 1 shows that the intervals between limit and operating values for German waste incinerators have been wide for years.

Air pollution control (APC) technology is typically built to extreme specifications in order to maintain operating parameters far below the legal requirements. The large gap between the actual emissions and the stipulated maximums indicates that the limits have not been exceeded.

Table 1. Selected Emission Limits for WtE Plants in Germany, in mg/Nm^3, Dioxins in ng TE/Nm^3, and Values Measured

All compounds in mg/Nm^3 Exception: PCDD/F in ng/Nm^3	17th BImSchV for MSWI (2016)	Values measured at MSWI plants until 2005 [3, 4]	Values measured at MSWI plants, 2014 [5]	Model plant, 2017 [6]	MSWI Bielefeld, annual averages 2016 [7]
Daily average					
Dust (Total Particulate Matter)	10	1	0.49	<2	0.34
Total Organic carbon (TOC)	10	1	n.a.	<0.1	0.31
Carbon monoxide (CO)	50	10	n.a.	<10	5.64
Hydrogen chloride (HCl)	10	1	2.16	<1	0.16
Hydrogen fluoride (HF)	1	0.1	n.a.	n.a.	0.063
Sulfur dioxide (SO_2)	50	1.5	6.9	<1	3.18
Nitrogen oxides (NO_x), measured as nitrogen dioxide (NO_2)	200	60	97	<80	21.4
Hg	0.03	0.002	0.0013	<0.001	<0.001
Average over a given period of time					
Sum: Cd + Tl	0.05	0.00005	0.00094	<0.01	<0.01
Sum: Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + Sn	0.5	0.017	0.016	n.a.	<0.01
Sum: As + Cd + Co + Cr (+ BaP)	0.05	n.a.	0.0023	n.a.	<0.002
PCDD/F in ng TE/Nm^3	0.1 ng	0.005 ng	0.0028 ng	<0.0015 ng	0.001

Nm^3 = standard cubic meters at 1.01325 bar and 273.15 K (0 °C)

Figure 1 illustrates this fact for dust using measured values at German incinerators in 2014. The analysis considers 188 combustion lines of 76 WtE plants with a capacity approaching 23.5 million tons each year. Each column represents one incinerator and the arithmetic means of all the measured daily average values for one year. Some plants indicate average values for their lines. Average values are based on the number of lines and are not averaged with waste throughput. The emission limit of the 17th BImSchV for dust was 10 mg/Nm³ (daily average). Figure 1 shows that even inferior incinerators operate in the range of 2 mg/Nm³, and numerous plants operate below the limit by a factor of 10. On average, almost no plant emits more than 2 mg/Nm³ daily. That is, nearly all plants emit less than 20% of the limit value of 10 mg/Nm³. These values are reliable, as MSWI plants measure dust continuously and provide results to the authorities “just in time” via the Internet.

Large and favorable discrepancies between emission limits and operating values also characterize other regulated pollutants. Only for nitrogen oxides is the comparison less evident, depending on the technology used.

The high APC standard of German WtE plants is illustrated by comparing data from the UK [8]. In 14 out of 22 MWIs operating between 2003 and 2010, PM_{10} emissions exceeding the EU limit of 10 mg/Nm^3 (daily average) were found (but usually <20 mg/Nm^3). The maximum value was 85 mg PM_{10}/Nm^3, followed by 66 (twice) and 54 mg PM_{10}/Nm^3. The authors of [8] refer to PM_{10} rather than the total suspended particulates (total dust) as size fraction studies revealed that all particulate incinerator emissions are less than 10 µm in diameter. The average value measured at Germany’s MSWI plants was 1 mg PM_{10}/Nm^3 until 2005.

Following emission protection regulations, authorities must, as part of the approval process, consider in each individual case whether meeting the guidelines of the 17th BImSchV (general state-of-the-art) is sufficient to protect people and the environment. Since the emission from WtE plants at a new location represents an additional load, the existing pre-load must be taken into consideration. The overall load must be well below the values that are considered critical from a health perspective (“safety margin”). The precautionary principle requires a conservative estimation of the emission forecast and the consideration of particularly exposed people in the context of risk scenarios (e.g., subsistence farmers at the point of maximum deposition). Thus, permit requirements for incinerators may in practice be significantly more ambitious than the requirements of the 17th BImSchV. In addition, operators can apply for more restrictive authorised limits. At MSWI Bielefeld, the permitted value for NO_x was set at 100 instead of 200 mg/Nm³, and the plant reached 21.4 mg/Nm^3 in 2016 [7]. Systems with such low emission levels are still within the upper third of incinerators now operating in Germany. In 2014, the average NO_x concentration of emissions at German MSWI plants was 97 mg/Nm^3. About half of the incinerators showed values below 50% of the emission limit (Figure 2).

Incinerators produce electricity, making it possible to calculate a “pollution backpack” of electricity produced in grams or milligrams of pollutant per kWh of electricity fed into the grid. These data can be compared to conventionally produced electricity. Electricity from waste incineration in Germany has a smaller backpack than conventionally produced electricity. These values make it possible to perform regional balances. A study on North Rhine-Westphalia, for example, concluded that waste incineration has improved the pollution balance there. For example, SO_2 equivalents have been curtailed by 3,300 tons per year and arsenic equivalents by 1.1 Mg/a [9]. Nonetheless, incinerators are not zero polluters despite the strict regulations and inspections, and noting how other industrial plants generate greater emissions is beside the point. The point is to estimate, per each individual case, the incremental burdens of a planned facility and how their stress can affect neighborhoods [10]. That determination is medically and environmentally important because it assesses the impact of new projected emissions atop existing emissions and loads. Germany calculates the incremental burden using a standardized

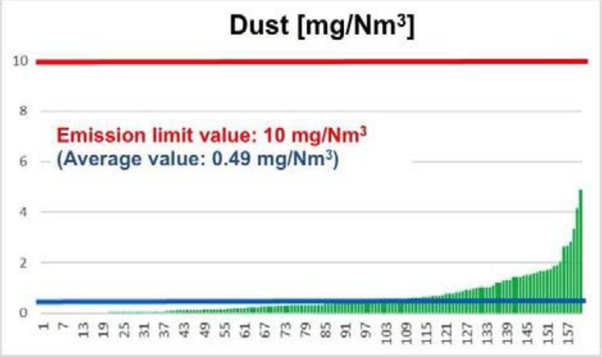

Figure 1. Range of Operating Values of German MSWI Plants 2014: Dust [5], Adapted

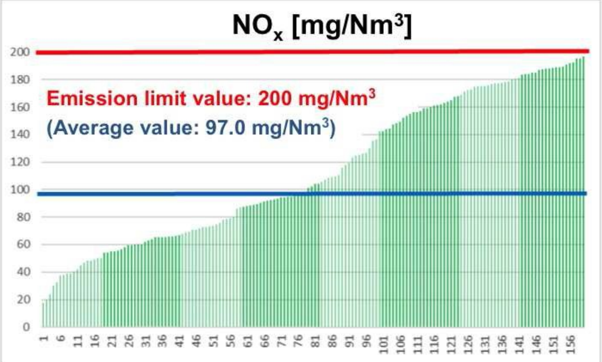

Figure 2. Range of Operating Values of German MSWI Plants: NO_x [5], Adapted

procedure regulated by the Technical Instruction on Air Quality Control (TA Luft: dispersion calculation has to use a Lagrangian particle model in compliance with the German guideline VDI 3945 Part 3). Total load in the proximity of a site is the existing load (background level, preload) plus the expected incremental burden from the planned facility.

Table 2 shows the existing loads and incremental burdens of organic pollutants at the MSWI plant near Lauta in former East Germany, which began operation in 2005. The report [11, p. 260] reads (translation by the authors of this study), “For both the organic substances as well as the (dust-bound) metals it is clear that the measured preload is virtually unchanged by the calculated additional burden. For the organic substances, the proportion of the additional burden on the total load is between 0.32% to 0.007%. For the metals, the proportion in the suspended particulate matter is in a slightly higher range between 6.63% and 0.04%, but in the dust deposition, however, only between 0.31% and 0.04%.

The question remains on whether accumulations (e.g., in soil around a plant) can occur over long periods despite slight incremental loads. In the 1980s and 1990s, the Environmental Agency of the Federal State of Bavaria (Bayerisches Landesamt für Umwelt – LfU Bayern) repeatedly studied vicinities near incinerators in order to determine whether persistent pollutants had accumulated, but they found none. Most measurements have since been adjusted [12].

Another concern is that individual pollutants may be extremely toxic causing concern even if incremental or total pollutants are minimal. For example, dioxins (polychlorinated dibenzo-*p*-dioxins and dibenzofurans, PCDD/PCDF) have been the locus of public debate on waste incineration even though they are no longer characteristic of this technique in Germany thanks to mandated multistage gas cleaning, as measurements at these plants confirm. Nowadays, dioxin emissions from other sources are a greater concern.

Germany’s MSWI operators must perform extensive single measurements several times annually. Even so, the margin between operating and limit values of 0.1 TE ng/Nm³ is high (Figure 3). In many systems, the margin exceeds an order of magnitude (a factor of 10).

The proper operation of an MSWI includes provisions for dealing with residual wastes. Incineration reduces the waste volume by about 90%, but the mass is reduced by about 70%. Substantial amounts of residual materials are produced. The largest residue streams are formed by slag falling from grates at the end of combustion. The slag contains scrap iron and metals that can be extracted (magnetic separation, sieving) and often profitably recycled. Slag itself can be recycled, for example, as materials for road construction. However, fresh slag has hydraulic properties and must be appropriately processed before being recycled (e.g., by adding water). Modern processing technologies can convert MSWI slag into viable secondary building materials for landfills and road construction.

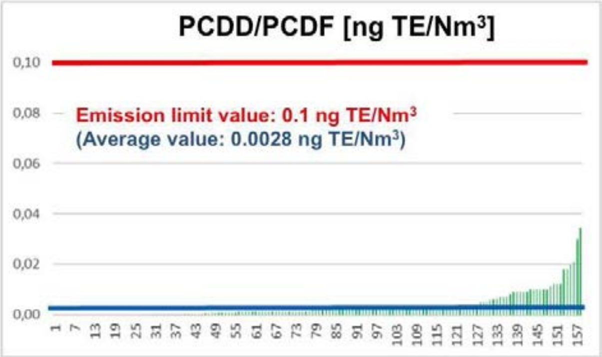

Figure 3. Range of Operating Values of German MSWI Plants: PCDD/PCDF [5], Adapted

Table 2. Preload and Incremental Load for Toxicologically Relevant Pollutants Calculated for a Planned MSWI [11]

Load	Pollutant	PCDD/PCDF	Benzo-a-pyrene	Benzene
Preload	Suspended particulate matter	60 fg/m³	0.72 ng/m³	2 µg/m³
	Dust deposition	3.7 pg/(m² x d)	–	–
Incremental load	Suspended particulate matter	0.14 fg/m³	0.0014 ng/m³	0.000143 µg/m³
	Dust deposition	0.012 pg/(m² x d)	0.12 ng/(m² x d)	–
Total load	Suspended particulate matter	60.14 fg/m³	0.7214 ng/m³	2.000143 µg/m³
	Dust deposition	3.712 pg/(m² x d)	–	–
Share of incremental load referring to total load	Suspended particulate matter	0.23%	0.19%	0.007%
	Dust deposition	0.32%	–	–

Table 3 shows the statutory limits for ashes and slags from waste incineration used as controlled secondary mineral construction materials in Germany [13]. The classes refer to conditions for use in technical construction (e.g., installation methods or properties of the groundwater layer outside or within water protection areas). Only the eluate has limits.

The principle of recyclability does not apply to APC residues (fly ash/filter dust, salts) because most pollutants enter the flue gas and are concentrated in these residues. Many organic compounds therein are POPs listed under the Stockholm Convention. Because of their pollutant content, fly ash and other APC residues should not be recycled but disposed of in safe, controlled landfills. Negative examples of "recycling" as food additives for poultry, fertilizers, or additives for agricultural soil or an unsecured disposal [14] show that an environmentally sound concept for the disposal of residual wastes is indispensable for gaining approval of a WtE plant.

Waste treatment seeks to destroy as much as possible harmful substances (and pathogens) in waste or, if impossible, to immobilize them (by incorporation into a matrix) or remove them from the environment (safe landfilling). This imperative also applies to pollutants formed during waste treatment such as POPs. POPs in stack gas emissions and in residues of APCS of waste incineration plants come from two sources. They are introduced into the plant by waste and partly withstand combustion (e.g., brominated flame retardants like PBDPEs and hexabromocyclododecane (HBCD) or organochlorinated pesticides, including DDT, as well as PCDD and PCDF). They are also products of incomplete combustion (PICs) of halogenated organic compounds introduced with wastes. These include chlorine-containing plastics, plasticizers (chlorinated paraffins), biocides/pesticides (PCP, lindane), or flame retardants (see above). PICs include PCDD/PCDF and also polybromochlorinated dibenzo-*p*-dioxins and dibenzofurans (PBCDD/PBCDF), PCBs, polychlorinated naphthalenes, and hexachlorobenzene. PCDD/PCDF is a guiding parameter for the efficiency of APC measures in incineration plants regarding POPs.

PCDD/PCDF are formed, and destroyed in incineration plants, but are also brought in with the waste. Germany reported PCDD/PCDF levels of 50–200 µg TEQ/Mg of municipal solid waste from households in the mid-1990s [15]. However, only 0.5–0.75 µg TEQ/Mg of waste incinerated was emitted via stack gas (average exhaust gas volume of 5,000–7,500 Nm^3/Mg meets the limit value of 0.1 ng TEQ/Nm^3 [Table 4, MSWI, Class 4]). Depending on the load of the waste and the technical standard, incineration plants can exhibit negative dioxin balances. That is, total outputs (stack gas plus generated wastes) are below the total inputs (e.g., [16]). This conclusion is supported by UNEP's Toolkit for *Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs* under Article 5 of the Stockholm Convention [17]. Here UNEP assumes emission factors for PCDD/PCDF in municipal waste incineration, which range from 0.5 to 3,500 µg TEQ/Mg of incinerated waste according to the standard of APCS (Table 4). Emission factors for MSWIs are assigned a medium confidence level and those for HWI are assigned a low confidence level.

Table 3. Material Values for Controlled Secondary Mineral Construction Materials: Ashes and Slags from Municipal (MSWI) and Hazardous Waste Incineration (HWI) [13]

Parameter	Unit	MSWI-1	MSWI-2	MSWI-3	HWI-1	HWI-2
Chloride	mg/l	160	5,000	5,000	920	2,300
Sulfate	mg/l	820	3,000	3,000	2,000	3,300
Fluoride	mg/l				4,7	8,7
Antimony	µg/l	10	60	150	30	150
Arsenic	µg/l				65	120
Chrome, total	µg/l	150	460	600	65	250
Copper	µg/l	110	1,000	2,000	130	500
Molybdenum	µg/l	55	400	1,000	400	1,890
Vanadium	µg/l	55	150	200	130	200

Table 4. PCDD/PCDF Emission Factors for the Selected Waste Incinerators (µg TEQ/Mg Waste Incinerated) [17]

Cat.	Class	Source categories	Potential Release Route [µg TEQ/Mg]		
			Air	Fly Ash	Bottom Ash
a		Municipal solid waste incineration (MSWI)			
	1	Low technol. combustion, no APCS Class 1 includes MSW incinerators that are simple, batch-fed furnaces with no APC systems and capacities of 500 kg/h or less.	3,500	0[A]	75[B]
	2	Controlled combustion, minimal APCS Class 2 includes MSW incinerators that are continuously fed, controlled combustors equipped with minimal APC systems, such as electrostatic precipitators, multi-cyclones and/or simple scrubbers.	350	500[A]	15[B]
	3	Controlled combustion, good APCS Class 3 includes MSW incinerators that are continuously fed, controlled combustors equipped with improved APC systems such as a combination of electrostatic precipitators and multiple scrubbers, a combination of spray-dryers and baghouses, or similar combinations.	30	200[A]	7[B]
	4	High tech. combustion, sophisticated APCS Class 4 is limited to state-of-the-art MSW incinerators equipped with sophisticated APC technologies, such as activated carbon adsorption units or SCR DeDiox$^{@}$ systems that should be capable of ensuring compliance with a strictly enforced regulatory value for air emissions in flue gases that is equivalent to 0.1 ng TEQ/Nm^3 at 11% O$_2$).	0.5	15[A]	1.5[B]
b		Hazardous waste incineration (HWI)			
	1	Low technol. combustion, no APCS Class 1 includes very small (< 500 kg/h) and simple furnaces operated in a batch-fed mode without any APC system for stack gases, e.g., muffle ovens, with flue gas volume flow rate of about 17,500 Nm^3/Mg of hazardous waste.	35,000	9,000	
	2	Controlled combustion, minimal APCS Class 2 includes HW incinerators with controlled combustion and minimal APC systems, with flue gas volume flow rate to 15,000 Nm^3/Mg of hazardous waste.	350	900	
	3	Controlled combustion, good APCS Class 3 incinerators have further improved combustion efficiencies and more efficient systems resulting in PCDD/PCDF concentrations of about 1 ng TEQ/Nm^3 (at 11% O$_2$). Also, the specific flue gas volume flow rate is reduced to 10,000 Nm^3/Mg HW.	10	450	
	4	High tech. combustion, sophisticated APCS Class 4 is limited to highly sophisticated hazardous waste incineration plants that are capable of complying with a regulatory value of 0.1 ng TEQ/Nm^3 (at 11% O$_2$), such as legislated in the in European Union. Class 4 represents the current state-of-the-art in HW incineration and APC technology with stack gas flow rates of some 7,500 Nm^3/Mg HW.	0.75	30	

A including dust from boiler and dedusting, residues from flue gas cleaning without filter dust, residues from flue gas cleaning and filter dust
B including slag

3. Results and Discussion

Conflicts over techniques and locations for technical facilities sometimes reached large proportions. Current conflicts over the proposed sites for WtE plants in China [18] or the decision of Indonesia's Supreme Court [2] show that the problem exists outside Germany and Europe. Could these conflicts have been prevented if more attention had been paid to public acceptance as an aspect of technology design? Scientific approaches have often failed because acceptance behavior is complex and hardly predictable. Nonetheless, we must address this difficult issue and find ways to increase acceptance of waste management projects.

Any incinerator or waste treatment facility in Europe must meet the emission control requirements (see above). Any facility that does not meet this standard or violates it during operation is unacceptable to the authorities. Besides technical standards, a successfully functioning WtE system depends on its technology and qualified and motivated staff. Orderly workflows, clear responsibilities, and an environmental officer assigned to top management are essential.

But will facilities that meet or surpass the legal requirements described above be accepted in the neighborhood for which they are planned? Experience shows that the expected or real emissions are major points of conflict in proposals to construct thermal waste treatment plants, other waste treatment facilities (e.g., MBT), and landfills. Minimum legal requirements in Europe govern emission control, and individual states like the Netherlands, Austria, and Germany impose incremental requirements (e.g., for flue gas cleaning).

Further, there is, as shown above, a considerable favorable interval between everyday emission values of Germany's incinerators and limits set by the 17th BImSchV. These coherences and corresponding data are widely available. Therefore, during many recent conflicts over new facilities in Germany, the acceptance question shifted to the performance of emission control systems. Opponents of planned sites insist that the proposed facilities attain the published values of and use the equipment employed by the best facilities. These citizens expect that "better" or "best" systems for pollution control should be installed. Figures 4 and 5 show differences in the cleaning performance among systems.

Will projects achieving high levels of pollution control find acceptance? In any public debate about a new location, they will generally face less resistance. Plants operating just below the legal limits for incinerators (17th BImSchV) face considerable opposition that has defeated many proposed sites and facilities.

Pollution control is only one area of conflict, however. In Germany and other European countries, authorities have access to measurement results in real time. In many cases, this access is granted to the public (Figure 6).

In addition, many MSWI plants install electronic display boards in their entrance areas that show the measured values in real time.

Economies of scale and ecological concerns might compel centralized (i.e., larger) plants or systems, and populations near planned sites may perceive load distributions as unfair. Those "unreasonable demands" placed on the site include the incremental emissions described above. When a planned standard is ambitious, the data above can be used to argue that emissions and risks are low compared to those from generally acceptable activities. It is possible to compare the benefits of technological progress to the status quo.

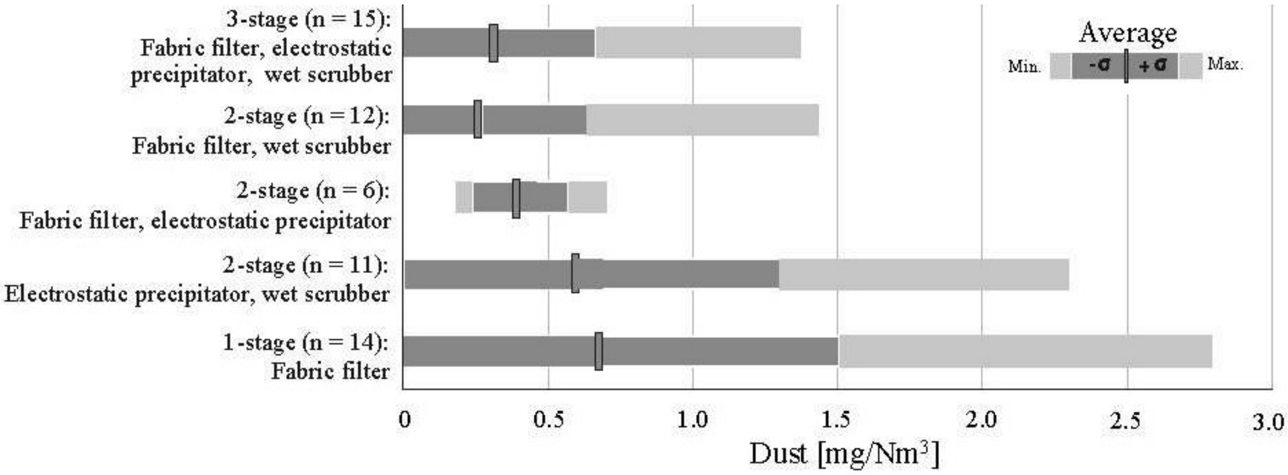

Figure 4. Comparison of Different Methods for Dust Removal [19]

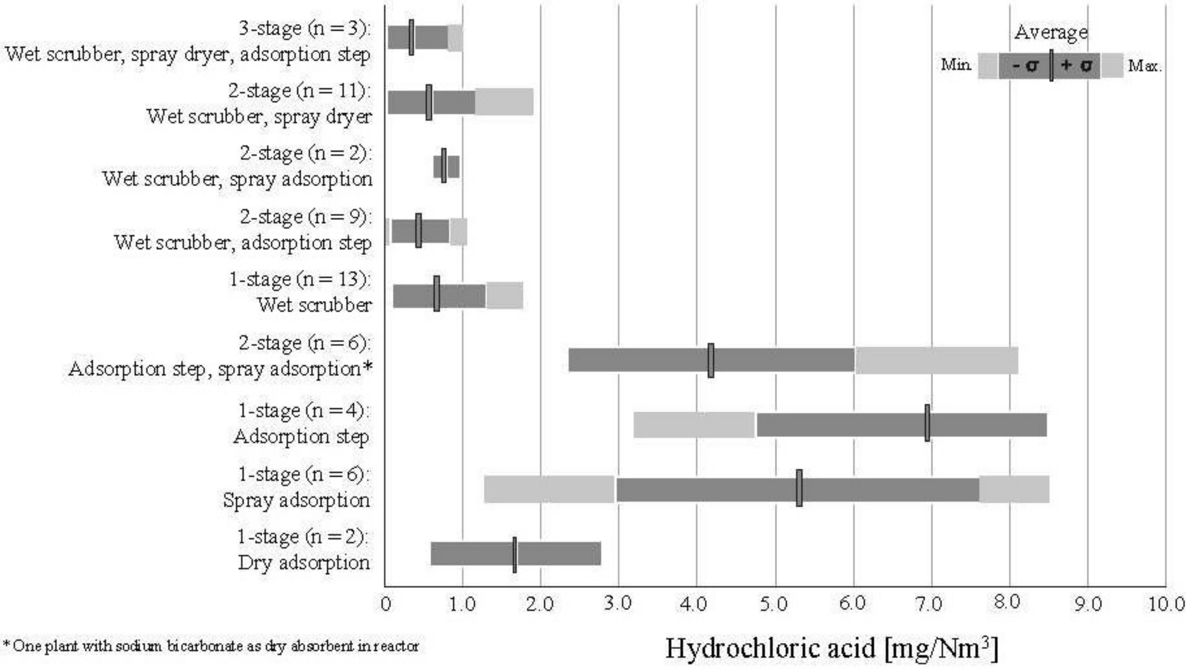

Figure 5. Comparison of Methods for HCl Deposition [19]

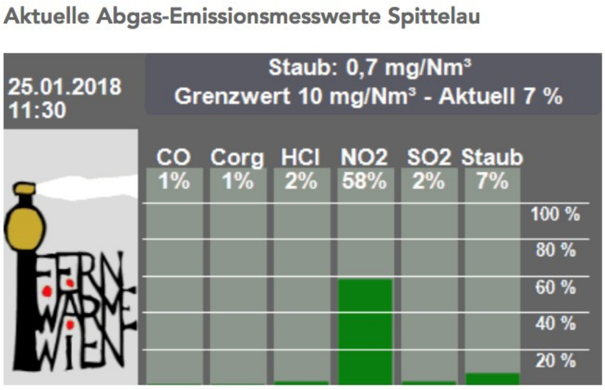

Figure 6. Results of Online Measurement made Public in Real Time, for Example, on the Internet, here by MSWI Spittelau (Vienna, Austria) [20]

Even so, it is disingenuous to dismiss concerns about a planned facility. Its traffic, noise, and visual impression can be undesirable irrespective of whether emissions are significant. Comparing the risks and emissions of a proposed plant to ordinary activities might not be persuasive. Many ordinary pursuits fall within the discretion and control of private individuals. While people who buy a new technical product choose to accept its externalities because they can control them somewhat, this is not the case at a site conflict. The comparatively few residents near central waste treatment plants bear the externalities of treating wastes generated by a huge number of others. Those externalities are present even if merely psychological, and they might depress property prices.

Studies establish that people consciously or unconsciously perform a personal risk-benefit analysis and form judgments. A planned installation does not likely present discernible personal benefits for inclusion in risk-benefit accounting. Even benefits such as new jobs, locally added value, or local sales seldom enter a personal calculation. This could change if site proposals included direct financial compensation, but that overture is absent in most site proposals.

The importance of pollution control systems for the acceptance of waste treatment facilities must not be under- or overestimated. State-of-the-art incinerators add miniscule amounts to pollutants on site. Given the nearly inevitable emergence of resistance, however, the proposed plants have a chance to be accepted at the beginning of the process only if they meet high APC standards. Experience shows that it is a prerequisite that operating values be below legally established values, even if system manufacturers must issue warranties.

Meeting a high pollution control standard, however, will not guarantee the acceptance of a plant. Many other motives – fear of accidents, fugitive emissions, additional traffic, noise, declining property values, and concern for nature or the landscape – are equally important. Incineration is an established and recognized technology in industrialized countries, but introducing it has generated controversy in the populace and the courts. This dispute is now settled in Europe, because the technology proves itself daily. As with all complex industrial plants, independent regulatory control must preside.

As prosperity in transitioning economies rises, the caloric count of waste will have rised as paper and plastics comprise a rising share of products. E.g. in Jakarta, the share of plastics and styrofoam on MSW composition rose from 3.7% in 1981 to 13.3% in 2005 and of paper from 7.8% to 20.6% during the same period [21]. Even so, a question arises as to whether it is reasonable for transitioning economies like Indonesia to approach the highest waste incineration standards despite the advantages.

Social problems such as lost jobs for waste pickers should be taken seriously. But "we should not idealize waste picking activities and operating conditions: Issues such as criminal activities, exploitation by middlemen, emerged elites, child labor and high occupational health risks need to be openly challenged…" [22].

In order to enhance social acceptability of WtE technologies and to support waste pickers, the Carbon Trust recommends the following in its report *Waste to Energy in Indonesia* [23]: "Separately, implementing WtE solutions may disrupt the livelihoods of waste pickers, who rely on established waste management practices for income. To address these issues, it is recommended that MEMR (Indonesian Ministry of Energy and Mineral Resources): a) Continue awareness raising activities and involve the public in developing local waste management plans; b) Use demonstration projects with strict environmental performance standards to show the public that plants are not harmful to health and the environment. These standards are likely to be required by international donor finance (…); c) Recognize waste pickers as an important group that needs to be considered when pursuing WtE solutions, and build capacity and financially assist them to work on upstream recycling" [23].

Following Bergecol et al., a "solution could lie in the regulation of an appropriate juxtaposition of this informal recycling sector and the vast, centralized, technical treatment systems in order to achieve a circularity of the flows at its best and allow at the same time positive socio-economic impacts" [24]. As one solution, Indonesia's Ministry of Environment has promoted waste banks (trash banks, garbage banks) as a program to bridge the gap between informal and formal waste management.

Hazardous chemicals in products often cause bigger problems for recycling than their treatment and disposal. High levels of POPs in products (many exported from industrial economies for reuse or recycling in developing economies) lead to site contamination because recycling fails to adhere to the best available techniques [25]. For example, "reprocessing of e-waste in parts of East Africa and South East Asia using environmentally damaging processes (e.g., acid leaching and open burning of wire insulation) have resulted in some of the most polluted places on the planet and devastated the health of entire communities" [22].

These substances are not destroyed. They re-enter the product cycle. So, the waste hierarchy in general and the 3R programs in particular can be realized successfully only if hazardous chemicals in products are addressed.

Chemicals in products are an emerging political issue in international chemicals management. The Strategic Concept for International Chemicals Management (SAICM) intends to deepen in the future. For example, SAICM's Chemicals in Products Programme of 2015 stresses the need for knowledge about constituent chemicals, particularly in materials intended for reuse or recycling, before disposal. The report observes the following:

41. Recyclers. *Chemicals in product information is a key component in achieving safe recycling and high quality recycled materials. Under current conditions, many recyclers need chemicals in products information, and are not themselves in a position to feed it into the manufacturing chain. Achieving effective and large-scale recycling is an important step on the road to greater resource efficiency and establishing sustainable materials use. As with numerous other overarching sustainability issues, access to chemicals in products information is an important contributory element. In view of this current status, the initial role of recyclers in the Programme is to identify their needs for chemicals in products information and to work with relevant stakeholders to gain access to the information. With access to sufficient information, recyclers could perform a role similar to that of the chemicals suppliers or those in the manufacturing chain described in paragraphs 38 to 40 above.*[1]

49. Waste managers. *The absence of relevant chemical content information exchange contributes to the legacy of improperly treated wastes and illegal trade in wastes. The decision to treat a material or product at end of life, by recycling or disposal, may depend on knowing its chemical content. Having such information on chemical content may lead to treatment choices—in particular the choice between reuse, recycling and incineration (or other disposal). There is a large and growing need for improved waste management which requires chemical information exchange systems tailored to the needs and*

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[1] Footnote 13 on page 11 in [26]: "Chemicals in products information for recyclers could be useful, as well-characterized materials would be of higher economic value and could be suitable alternatives to virgin materials. In both cases, chemicals in products information could be used to reintroduce materials with full knowledge of the chemicals of concern that they contain."

capacities of the waste management sector, including the informal sector, and of government officials. The role of waste managers in the Programme is initially to identify their chemicals in products information needs and to work with holders of information to achieve access" [26].

Besides containing hazardous chemicals, many products cannot be recycled. E.g., additives in plastics can massively hinder the recycling of large quantities of plastic products (for example Cd stearate in PVC profiles). The Carbon Trust points out that "it is crucial to note that many types of plastic are not recyclable, and can only have some value recovered in MSW incinerators. This should guarantee a significant material flow to MSW incineration plants downstream from recycling plants" [23].

Figure 8 depicts examples from packaging, the complex components of which need to be reconstituted to be recyclable and available as (secondary) materials for new products. Options to recycle multilayer packaging are currently available, but have drawbacks like a limited scope or a high expenditure of energy [27].

International standards are needed to make "design for recycling" or "design for recyclability" (or "design for sustainability") obligatory, not only for packaging, but for other products, too. Given the globalization of the stream of goods and wastes, it seems necessary to impose responsibility upon manufacturers and distributors to "recycling-friendly" products. Imposing this responsibility on them has a regulatory basis in numerous EU directives and national regulations. However, existing regulations are insufficient because they concern only selected product groups (cars, batteries, electronic devices, and packages) and do not apply in all markets worldwide. This problem can be solved only on an international level, most likely by binding specifications for chemicals in and design for recycling of products.

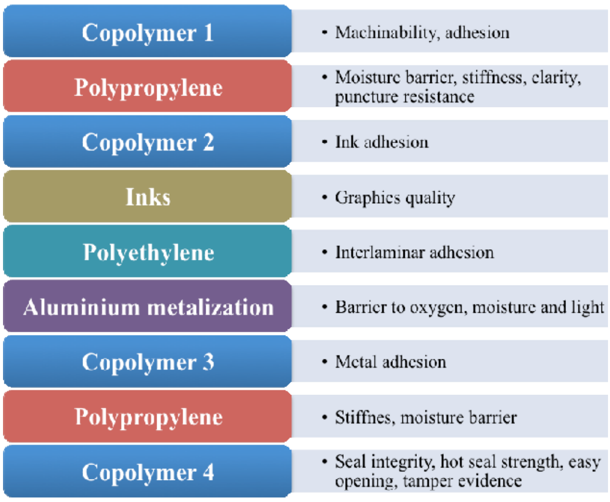

Figure 8. Cross section of a Chip Bag from Inside to Outside (Own Graph, based on [28])

Destroying organic pollutants (and pathogens) by state-of-the-art incineration is less problematic for human health and the environment than getting rid of them in unsecured landfills or in open combustion. Science is obligated to review data regarding the emission behavior of waste incineration for use in transitioning economies. A comparison of technological options for waste management should be made available to courts and political decision-makers.

4. Conclusions

Confidence in the statements of government and government agencies as well as on those who support is an important point of creating and increasing acceptance. In the case of the installation of waste into energy (WtE), independent scientific bodies such as universities can contribute to this process by the measurement of emissions and their evaluation. Supervision and control is another important building block in increasing acceptance. It is important that the results of self-monitoring and regulatory control and monitoring are publicly available. Unfiltered access to data through the Internet is a matter of great concern.

Many products that enter the waste stream contain heavy metals, persistent organic pollutants, and other harmful substances. A "circular economy" has to cope with enormous challenges concerning the management of pollutants contained in products or wastes. This challenge can be solved most likely by binding specifications for chemicals in and design for recycling of products.

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