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A comparison of electronic waste recycling in Switzerland and in India

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Abstract

Electronic waste, commonly known as e-waste, is comprised of discarded computers, television sets, microwave ovens and other such appliances that are past their useful lives. As managing e-waste becomes a priority, countries are being forced to develop new models for the collection and environmentally sound disposal of this waste. Switzerland is one of the very few countries with over a decade of experience in managing e-waste. India, on the other hand, is only now experiencing the problems that e-waste poses.

The paper aims to give the reader insight into the disposal of end-of-life appliances in both countries, including appliance collection and the financing of recycling systems as well as the social and environmental aspects of the current practices.

Keywords: E-waste; Recycling; Hazardous waste management

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1. Introduction

Electronic waste recycling is gaining currency around the world as larger quantities of electronics are coming into the waste stream. Managing the increasing volumes of e-waste effectively and efficiently–in cost and environmental impact–is a complex task. Firstly, special logistic requirements are necessary for collecting the e-waste. Secondly, e-waste contains many hazardous substances which are extremely dangerous to human health and the environment, and therefore disposal requires special treatment to prevent the leakage and dissipation of toxics into the environment. At the same time, it is a rich source of metals such as gold, silver and copper, which can be recovered and brought back into the production cycle. This particular characteristic of e-waste has made e-waste recycling a lucrative business in both developed as well as developing countries. While some countries have organised systems for the collection, recycling, disposal and monitoring, other countries are still to find a solution that ensures jobs while minimizing the negative environmental impacts of e-waste recycling. This paper presents a comparison of the end-of-life treatment of electronics in two countries, Switzerland and India.

Switzerland was chosen because it was the first country to implement an industry-wide organised system for the collection and recycling of electronic waste. Having been operational for a decade, the Swiss system provides the best opportunity to study the evolution of an e-waste management system. India was chosen as the other country for study because it is not only among the fastest growing markets for the consumption of electronic appliances, but also because it has a large recycling industry and has emerged as a major market for old and junked computers (Agarwal et al., 2003).

The purpose of this paper is twofold. The first is to provide a description of the current e-waste management system in the two countries. The second is to compare the two systems and understand how and why they differ. The comparison is being made only of the overall national situations in each country, looking in each case at only a few interesting social and environmental aspects.

Data and information for both case studies was collected through personal interviews with leading experts, senior management of appliance manufacturers as well as high ranking government officials responsible for environmental policy. The Indian case study is based primarily on a pilot study conducted by Empa[1] in Delhi in 2003–2004 (Empa, 2004). The authors assume that the pattern of e-waste handling in the rest of India, mainly the large urban centres, is similar to that of New Delhi.

2. E-waste recycling in Switzerland

2.1. Background

Switzerland, with one of the highest per capita incomes in the world,[2] is also among its most technologically advanced countries. The total installed PC base in Switzerland is

[1] Empa—Swiss Federal Laboratories for Material Testing and Research.

[2] Estimated GDP per capita for 2003 was US$39,800 according to World Bank World Development Indicators, 2004.

3.15 million PCs, which translates into one PC for almost every two persons (World Bank, 2004), over 99% of the households have refrigerators and over 96% have TVs (Euromonitor, 2003). Even though market penetration of electrical and electronic goods is high, the market for new appliances remains strong, with annual per capita spending on ICT products topping US$3600, the highest in the world.

Switzerland also ranks among the top countries in the world regarding environment protection. Ranked 7th on the 2005 Environmental Sustainability Index (Esty et al, 2005), its score of 1.39 for Environmental Governance[3] ranks it seventh in the world. Environment concerns as well as consumer awareness regarding environmental issues is high, and in a recent study (SAEFL, 2004), 62.6% of the citizens wanted the government to place more emphasis on environmental issues. The Swiss law on waste management stresses the 'polluter pays principle' and has encouraged the reduction, reuse and recycling of waste. There are several systems in place for segregating and collection of different kinds of waste such as glass, paper, plastic bottles and aluminium, among others, to facilitate better recycling.

Not surprisingly, Switzerland is the first country in the world to have established a formal system to manage e-waste. Even though the 68,000 tonnes of e-waste collected in Switzerland in 2003 represented only 2.6% of the waste stream,[4] it corresponds to a little over 9 kg/capita[5]—substantially more than the 4 kg/capita target set by the EU in the WEEE Directive (EU, 2004). The effective collection of e-waste in Switzerland is primarily due to the efficient management of the waste stream by two Producer Responsibility Organisations (PROs)—SWICO[6] and S.EN.S.[7] Along broad lines, SWICO manages 'brown goods'—electronic equipment such as computers, TVs, radios, etc., while S.EN.S handles 'white goods' such as washing machines, refrigerators, ovens, etc.

Both SWICO and S.EN.S have more than a decade of experience in managing e-waste, having started their e-waste programs based on the principle of Extended Producer Responsibility (EPR), well before it became legally mandatory. Lindhqvist (2000), one of the pioneers of EPR, defines it as "an environmental protection strategy to reach an environmental objective of a decreased total impact from a product, by making the manufacturer of the product responsible for the entire life cycle of the product and especially for the take back, recycling and final disposal of the product".

Legislation on e-waste management was introduced into Switzerland only in 1998, when the Ordinance on 'The Return, the Taking Back and the Disposal of Electrical and Electronic Appliances' (ORDEA) (SAEFL, 1998) came into force.

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[3] High environmental governance scores mean higher quality of environmental regulations, transparency of decision making and existence of sectoral guidelines for environmental impact assessment. See *2005 Environmental Sustainability Index*, Yale Center for Environmental Law and Policy World Economic Forum (http://www.yale.edu/esi/), and *Center for International Earth Science Information Network* (http://www.ciesin.columbia.edu/) for more information.

[4] Calculated on the basis of 2.58 million tonnes of municipal waste generation. From SAEFL statistics on development of municipal waste in Switzerland, June 2004.

[5] 9.25 kg/capita based on an estimated Swiss population of 7,350,000 taken from SAEFL statistics on development of municipal waste in Switzerland, June 2004.

[6] SWICO—The Swiss Association for Information, Communication and Organisational Technology.

[7] S.EN.S—Stiftung Entsorgung Schweiz.

2.2. System overview

The collection and recycling of e-waste in Switzerland is an intentionally developed and organised system. As mentioned before, the Swiss system is based on EPR—both legally and operationally. This places both the physical as well as the financial responsibility of an environmentally sound disposal of end-of-life electronics with the manufacturers and importers of these products. The entire operative responsibility is however with the two PROs–SWICO and S.EN.S–who manage and operate the system on behalf of their member producers. This also ensures that there is a clear definition of roles and a demarcation of responsibilities. Fig. 1 shows a simplified model of the material and financial flows within the Swiss system.

One of the pillars of the system is secured financing of the collection and recycling by way of the Advance Recycling Fee (ARF) charged on all new appliances. The ARF is used to pay for the collection, the transport and the recycling of the disposed appliances. The ARF can range from a minimum CHF (Swiss franc) 1 on small items, such as hair dryers and electric shavers, to up to CHF 20 for TVs or CHF 40 for refrigerators. The total ARF collected in 2003 was CHF 71.66 million.

Table 1 shows a breakdown of the expenditure under the main heads of recycling, transport and collection. It is seen that the largest portion of the ARF went to the recyclers, totalling CHF 41.41 million for the year 2003.[8] S.EN.S paid CHF 18.01 million, representing 49% of the ARF collected on small and large household goods, towards recycling expenses. SWICO paid CHF 23.40 million, representing 67% of the ARF it received, in recycling costs.

Setting a recycling fee that is at the same time easy to understand, transparent to administer and yet does not cross-subsidise[9] product categories or cause consumer resentment is indeed a difficult task. The Swiss ARF is an intergenerational contract between appliances purchased in the past and those that will be purchased in the future, akin to a pension system. The risk of setting such an intergenerational fee is that it requires accurate estimations of how much waste will be generated and how many new products will be sold. While the ARF model has so far been successful, there is a danger that the fees collected on new appliances may not be sufficient to recycle the discarded appliances. The other drawback of an ARF could be that there is a cross subsidisation of products among different categories—a situation where, for example, PC buyers pay for the recycling of tape recorders. To avoid such discrepancies, both SWICO and S.EN.S have distinct categories of products according to the approximate cost of recycling them.

Another key feature of the system is its comprehensive scope and nationwide acceptance. SWICO and S.EN.S had 500 official collection points (in 2003) around Switzerland in addition to the thousands of retail locations which have to take back old equipment free of charge, irrespective of the brand or year of manufacture, thereby making it easier for consumers to dispose of their e-waste at appropriate locations. SWICO and

[8] SWICO Annual Activity Report 2003 and S.EN.S Annual Activity Report 2003.

[9] Cross subsidising would occur if the ARF charged on one category of products, for example photocopiers, were much higher than the copiers' recycling cost, and the differential were then be used to pay for the recycling of another category of products, for example TVs, which may have recycling costs higher than the ARF charged.

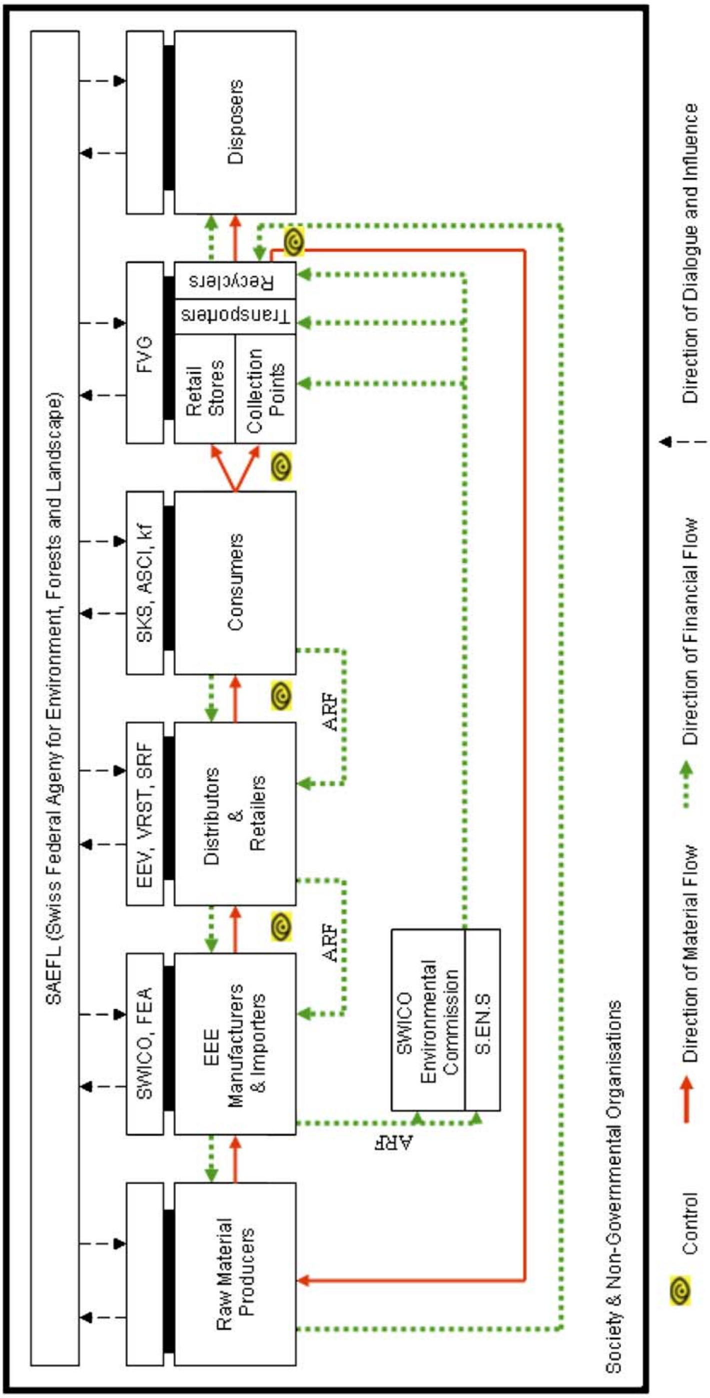

Fig. 1. Material and financial flows in Swiss e-waste.

Table 1
SWICO and S.EN.S income and expenditure in the year 2003

For period 01.01.03–31.12.03	SWICO	S.EN.S	System total
Income (in million CHF)			
Total ARF income	33.66	38.00	71.66
Expenses (in million CHF)			
Recycling expense	23.40	18.01	41.41
Transport and logistics expense	4.54	5.96	10.50
Collection point expenses	1.75	3.86	5.61
Others (PR, Controlling, Administrative, etc.)	5.24	4.26	9.50
Total expenses	34.93	29.98	64.91

S.EN.S together paid almost CHF 5.6 million, or approximately 8% of the total ARF received in 2003, to the collection points and a little over CHF 10.5 million for transport of the waste collected. In all, the collection and logistics expense was over CHF 16.1 million, representing almost 22.5% of the ARF received. By having common collection points, the PROs are better able to manage logistics, benefit from economies of scale and provide a consumer friendly, all-inclusive solution instead of a prohibitively expensive brand-specific one.

One of the pillars that facilitates the smooth functioning of the system is the multiple levels of independent controls which are able to check free riding and pilferage as well as to ensure that the recyclers maintain quality and environmental standards. Both material and financial flows are controlled at every stage, as can be seen in Fig. 1 above. The independent controls not only deter free riders, but also give credibility to the entire system, thereby also ensuring the participation of retailers and consumers.

Rigorous controls also prevent the illegal import and export of e-waste to and from Switzerland. Section 3, Article 9 of the ORDEA (SAEFL, 1998) lists the provisions for the export of appliances for disposal. It specifies that an exporter needs to provide documentary evidence that the final disposal of e-waste is done in an environmentally tolerable manner and has the prior consent of the importing country. As a signatory to the Basel Convention Ban Amendment, Switzerland does not permit the export of e-waste to non-OECD countries.

While this system has been functioning smoothly for the past decade, there is concern that it might lead to PRO and recycler monopolies, disadvantaging consumers in the long run. However, waste management and recycling fields in particular have always been connected with the problem of monopolies (Lindqvist, 2000). To minimize concerns both PROs and recyclers maintain transparent contract procedures and are also inspected by regulatory authorities.

3. E-waste recycling in India—the New Delhi case study

3.1. Background

India, with over 1 billion people, is the second most populous country in the world (World Bank, 2004). Although the penetration of India's market for consumer durables is substantially lower than that of developed countries, the size of India's market in absolute terms is larger than that of many high-income countries. Moreover, India is one of the fastest growing economies of the world and the domestic demand for consumer durables in India has been skyrocketing. From 1998 to 2002, there was a 53.1% increase in the sales of domestic household appliances, both large and small (Euromonitor, 2004). The growth in PC ownership per capita in India between 1993 and 2000 was 604% compared to a world average of 181%. As a result, the total PC base during this period has grown from an estimated 450,000 PCs to 4,200,000 PCs (WITSA, 2002).

Unfortunately, economic growth and environmental protection indicators are at odds with one another. India ranks an abysmal 101th on the 2005 Environmental Sustainability Index (Esty et al, 2005), and for Environmental Governance gets only the 66th rank, with a score of -0.10 (the highest being Iceland with 1.65 and the lowest Iraq with -1.52). Environmental concerns among manufacturers as well as the awareness of consumers regarding environmental issues are not very high. While the government has passed several environmental protection laws, their enforcement remains questionable. However, there is increasing pressure on both the government as well as the private sector from strong environmental NGOs.

While environmental concerns take a back seat amid more pressing problems, Indians culturally are loathe to waste, and this ensures that electrical and electronic products often find second- and even thirdhand users farther down the income chain. Furthermore, recycling is a market-driven and growing industry in India, albeit one driven by economic necessity associated with poverty (Haque et al, 2000).

A report by a New Delhi based NGO, Toxics Link, on computer waste, estimated that in India business and individual households make approximately 1.38 million personal computers obsolete every year (Agarwal et al, 2003). Results of the Empa field study (Empa, 2004) suggest that the computers coming into the recycling market in India are of a much older vintage than those in Switzerland. This is likely because the useful life of a computer, like most electrical and electronic appliances, is much longer in India than in Switzerland.

In addition to post-consumer e-waste, there is also a large quantity of e-waste from manufacturing in the form of defective printed wiring boards, IC chips and other components discarded in the production process. This e-waste is being recycled, too.

Legally, electronic waste is included under List-A and List-B of Schedule-3 of the Hazardous Wastes (Management and Handling) Rules, 1989, as amended in 2000 and 2003 (MoEF, 2003). However, this does not stipulate the management and handling of post-consumer waste generated within the country, merely stating that any e-waste import requires specific permission of the Ministry of Environment and Forests. No such permission has been given to any authority or person by the Ministry thus far. However, there have been unconfirmed reports in the media about illegal imports (MoEF, 2004).

3.2. System overview

Unlike the sophisticated collection, transportation and recycling system in Switzerland, the Indian system has developed very organically, as a natural branching of the scrap

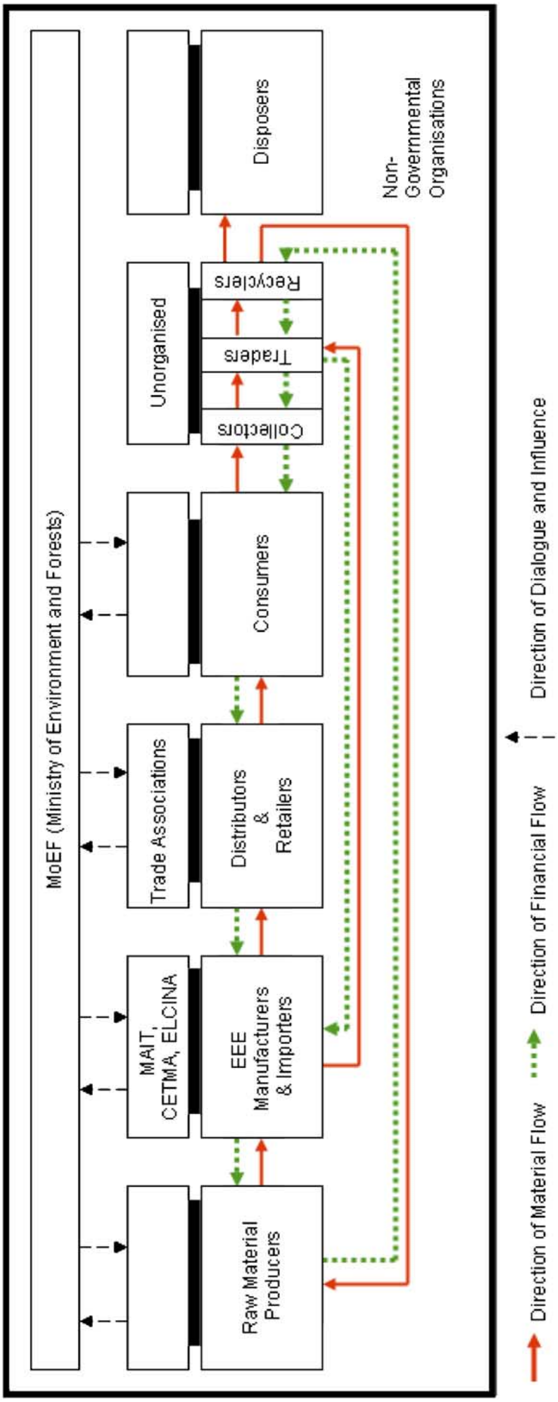

Fig. 2. Material and financial flows in Indian e-waste.

industry which accepts scrap from many sources including old ships, end-of-life vehicles and building wastes. With the advent of the electronic age, and as electrical and electronic appliances started becoming obsolete, the already established scrap metal industry absorbed this new waste stream to recover metals, which are then used as a feedstock to steel mills and non-ferrous smelters and refiners. Industrial recycling networks or industrial symbiosis are systems of many different firms and other organisations and societal actors that cooperate through common waste material and waste energy utilisation (Korhonen et al, 2004). Thus in India, the e-waste management system is a case of successful industrial symbiosis which is self-organised and market-driven, as described by Pierre Desrochers (2004).

In contrast to Switzerland, where consumers pay a recycling fee, in India it is the waste collectors who pay consumers a positive price for their obsolete appliances, as can be seen in Fig. 2. The small collectors in turn sell their 'collections' to traders who aggregate and sort different kinds of waste and then sell it to recyclers, who recover the metals. Fieldwork during an Empa pilot study in New Delhi (Empa, 2004) indicated that the entire industry is based on a network existing among collectors, traders and recyclers, each adding value, and creating jobs, at every point in the chain. As the volume of e-waste has grown, a noticeable degree of specialisation has emerged, with some waste processors focussing only on e-waste. Given the low level of initial investment required to start a collection, dismantling, sorting or recovery business, it is attractive for small entrepreneurs to join the industry. This 'recycling network' is substantiated by similar results of fieldwork by Baud et al (2001) on solid waste management in Chennai, India, which found a series of private–private relationships among waste pickers, itinerant buyers, dealers, wholesalers and recycling enterprises. The main incentive for the players is financial profit, not environmental or social awareness. Nevertheless, these trade and recycling alliances provide employment to many groups of people (Baud et al., 2001). E-waste recycling has become a profitable business, flourishing as an unorganised sector, mainly as backyard workshops (Empa, 2004). Unfortunately, given the unorganised nature of the business, there are no figures available regarding the scale of the business or the number of people it employs. For Delhi, Empa's pilot study estimates the number of unskilled workers in recycling and recovering operations to be at least 10,000 people (Empa, 2004). The biggest drawback of the current Indian system is the uncontrolled emission of hazardous toxics that are going into the air, water and soil. The health hazards from fumes, ashes and harmful chemicals affect not only the workers who come into contact with the e-waste, but also the environment.

4. Comparison of the two systems

From the two case studies above, it is clear that the e-waste management systems in the two countries are very different. Based on observations of both systems, a qualitative comparison is done using four criteria:

- E-waste per capita
- Employment Potential

- Occupational Hazards
- Emissions of Toxics

These criteria were chosen because they feature prominently in discussions related to e-waste. The criterion 'E-waste per capita' was defined as the annual accrual of e-waste per capita. The two criteria, 'Employment Potential' and 'Emissions of Toxics', are in reference to an annual quantity (e.g. 1 metric tonne) of a reference material. As reference material obsolete PCs were chosen because they represent a combination of the typical characteristics of electronic equipment such as printed wiring boards, cables and high value metallic connectors as well as the CRT, which requires special recycling techniques. The reference material is not specified any further as its exact composition is not relevant for our qualitative assessment (cf. the article by Martin Streicher-Porte et al. in this issue). The criterion 'Occupational Hazards' references to an average workplace in e-waste recycling, taking into account the whole recycling chain including collectors, traders and dismantlers.

The 'E-waste per capita' can be considered as a result of two determining factors:

- the market penetration of EEE
- the EEE intensity per service unit, e.g. the unit "one hour of PC use".

A higher value in either factor leads to a higher annual accrual of e-waste per capita. Compared to India, Switzerland shows a higher value for both factors with its more widespread use of appliances (see Section 2.1) and shorter product service lives, given the lower rate of repair and reuse. EEE intensity per service unit is inversely proportional to the average service life. Thus, Switzerland has a much higher annual accrual of e-waste per capita. In the year 2003, more than 9 kg of e-waste per resident were taken back in Switzerland by the SWICO and S.EN.S recycling systems (SWICO, 2004). This is more than double the EU target level of 4 kg per capita set in the WEEE directive (EU, 2004).

Using the *Employment Potential* offered by the system as one criterion to judge the social impact of the system, it can be seen that the Indian system generates far more jobs than the Swiss system per tonne of e-waste processed. Collection, dismantling, sorting and segregation and even metal recovery are done manually in India. Therefore, the e-waste recycling sector, albeit informal, employs many unskilled or semi-skilled workers. While there are no national figures yet available, estimates of the Empa pilot study (2004) show that at least 10,000 people are involved in the recycling and recovery operations in Delhi alone. The figure would be much higher if the entire value chain of collectors, transporters and traders were included. Comparatively, e-waste management in Switzerland is highly mechanised, and employs far fewer people. For example, the S.EN.S recycling system, which manages discarded household appliances totalling over 34,000 tonnes (for all of Switzerland), engages 470 persons in all-including collection, transportation, recycling, administration and controlling (S.EN.S, 2004). The main reason for this large difference in the number of people employed, is the availability of cheap manpower in India as compared to the high labour costs in Switzerland. An

Table 2
Evaluation results for the comparison criteria

Criterion	Switzerland		India	
	Level	Implication	Level	Implication
E-waste per capita	High	Negative	Low	Positive
Employment Potential	Low	Negative	High	Positive
Occupational Hazard	Low	Positive	High	Negative
Emissions of Toxics	Low	Positive	High	Negative

e-waste recycler in India earns approximately CHF 4.1 per day,[10] as compared to CHF 150[11] in Switzerland.

However, when considered from the perspective of *Occupational Hazard*, e-waste handlers in India are at a much higher risk than in Switzerland. One reason for this is the low level of awareness among workers regarding the hazards of the chemicals and process they are exposed to and the minimum protection and safety measures they are obliged to take. The other reason is the lack of formal guidelines as well as a lax enforcement of existing environmental laws.

The *Emissions of Toxics* into the environment is another aspect to consider. Due to the manual processes used for materials recovery, the level of toxics such as dioxins and acids released has been found to be much higher in India than in Switzerland. Culpable for the high levels of these externalities are backyard processing techniques such as open burning of cables, which is conducted in the open without any controls or precautions. The material flow in and out of the system is totally unmonitored at present. In contrast, the Swiss system imposes high safety and emission standards and emphasises the implementation of regular controls and monitoring at every stage of the material and financial flow through the system. External auditors mandated by the PRO's carry out at least one annual audit at each recycler, and unless standards are complied with, the recycler's licence is revoked. This monitoring has the effect that the e-waste recyclers stay within the strict Swiss emission limits.

Table 2 summarizes our evaluation results for the four criteria for Switzerland and India.

5. Conclusion

The growing quantity of e-waste necessitates the development of systems which can handle the waste in such a way that minimizes negative social and environmental impacts while maximizing the positive impacts. By comparing different systems, potential areas of improvement can be identified and positive aspects of other systems can be adapted to improve the existing system.

[10] Average wage Rs. 150/day calculated at an exchange rate of Rs. 36/CHF. Empa (2004) New Delhi Pilot Field Study.

[11] Average minimum monthly wage of CHF 3000, considering 20 working days per month.

The most important conclusion from our analysis is that there is no one-and-only solution for e-waste recycling systems. What could be defined as an optimal solution depends very much on the economic and cultural context in which the system operates. The cost of labour, the structure of the economy including the important informal sector, the existing regulatory framework and the possibilities and limits of law enforcement have to be taken into account in order to find solutions that can improve the situation with regard to environmental impacts, occupational hazards and economic revenue. In order for a recycling system to be sustainable, it must also have the ability to adapt flexibly to future changes in the quantity and quality of the waste flows. Greater flexibility might be an advantage of systems that have emerged from the market, albeit in the informal sector, as opposed to systems that are based on an intergenerational contract.

As this paper gives only a first qualitative review of the environmental and social aspects, there is a need for more quantitative measures in the area of e-waste recycling. That could provide a basis for modelling different interventions and for fine tuning their effects.

As governments, municipalities, manufacturers and NGOs discuss how to manage e-waste, there is a clear need for multi-disciplinary research in the field. One important direction for further research would be to quantitatively estimate and project the flows of e-waste worldwide, as well as their social, environmental and economic costs. From a business perspective, it would be interesting to study the potential and the dynamics of the e-waste recycling market. From a policy perspective, further research into the applicability, effectiveness and efficiency of various instruments for managing e-waste is needed.

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