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The Geography of Textile Production and its Damaging Processes to the Environment

Abstract

The authors in this article combine their different research backgrounds in geography and fine art to discuss and analyse the damage caused by the textile industry to the living environment.

To begin with textile production is described geographically including where and which Asian countries are considered as the main contributors to pollution through textile production. Secondly, the authors go into specifics on how a textile production, such as cotton, can have multiple processes, all in which include their own damaging effects to the environment. With the majority of our textiles coming from Asia, it is of no surprise that India, for example, has 35 million employees in textile factories and production alone. With the economic growth of Asia's textile world being increasingly successful, what downsides are there to this 24/7 business and what is being done to protect the environment surrounding textile factories and sites?

Key words

Textile production; Harmful chemicals; Fibre; Asian textile manufactory; Cotton

1. Introduction

According to a wide range of resources we used to develop our knowledge on this topic (see *Research Methods* at *Section 3*), we can state that in developed countries, every process and processing method in the textile and clothing manufacture industries are regulated by strict environmental rules. These types of factorial activities go with the most notable environmental pollutions that are closely affecting the human living sphere. The countries involved in production have long been exporting their products to those areas of the world where profit and economic growth come before the protection of the natural environment. The loose or non-existent environmental regulations and technological rules—both on a short and long run—lead to severe contamination that can both harm the human and physical spheres respectively.

2. Aims of the study

Whilst preparing this paper, we approached the topic mainly from two aspects: geographical and environmental, but wrote it as a co-operation between a geographer and a fine artist, which led us to other areas to discover and study, such as chemistry, technological processes, machinery, product material development and usage, and trade. With this article we aimed to reflect on the textile industry and how its current technologies and processes affect the environment. We concentrate on *Asia*'s traditional textile producing countries and focus on their impact of and contribution to global environmental issues.

3. Research methods

Throughout the research of this study, we relied on recent statistical data that was mainly provided by the *European Commission (EC)*, the *International Labour Organization (ILO)* and the *World Trade Organization*. We collected information from specialist websites on the internet, but we also used a significant number of scientific papers written by mainly Asian authors in last 15 years, for example CHAVAN, R. B. (2001); MIA, C. M. (2001); MALIK, A. S. (2002); SHAH, B. (2002); HAYDAR, S. – BARI, A.

(2009); DANG, T. D. *et al.* (2010); RUPP, J. (2010); KANT, R. (2012); MERK, J. (2012) and YADAV, I. C. *et al.* (2014). We also used some hard copy books written by, for example, SLATER, K. (2003); BERNERS-LEE, M. 2010; RIELLO, G. (2015). For preparing the visual material for this paper we used *CorelDraw X6*, *MS Word* and *Excel*, and an online map image maker called *P&P World Map*.

4. The geography of textile production

The development of organic chemistry in the beginning of the 20th century revolutionised the methods and processes that had previously been used in the textile industry. Initially a variety of materials were used to produce synthetic basic materials. However, most of the compounds of applied chemistry are harmful to the living spaces and environment that can still be traced in the soil and water reserves. In the newly industrialising countries (NICs), the following environmental hazards are still uphold:

- air and heat contamination,
- the change of pH level (acidification),
- bleaches, colourings (dyes) and optical whiteners,
- non-biodegradable chemical compounds.

KALBERLAH, F. – SCHWARZ, M. (2011) demonstrate that the imported clothing and textile products from *East Asian* countries are not complied with European norms and there may be invisible threats to humans and to the environment. The propagation of modern and innovative production technologies and procedures are hindered by economic and political processes. This retroaction may affect the physical environment and, in most cases, it can lead to irreversible changes. On the long run, it may demolish local, natural values, and on the short run—by the presence of carcinogen and mutagen compounds—it can cause sever health problems and lead to illnesses. The average consumer is bombarded by false facts regarding environmental hazards; therefore, it is important to draw up a comprehensive picture of the textile industry's physical, economic and regional situation and current positions.

Based on the *World Trade Organization*'s statistics of 2012, the countries that form the backbone of the global textile and clothing production can be specified. Moreover, by using this statistical data, tendencies can also be drawn up for those countries where previously they had almost no textile industry, but which has become a significant economical factor in the last 10 years with a notable market share.

According to the export of the *World*'s three largest continents, half of the trade of textile products happen within the regions of Asia and *North America*. In *Europe*, three quarters of the trade deals are made within the continent's boundaries. In *Asia*, *China* plays a key role which in 2012 exported 33.4 million USD worth textile products; the other significant countries in *Asia* are *India*, *Pakistan*, *Vietnam* and *Thailand*. However, the textile industry's share of export within a country's overall industrial production gives a much different view: *Pakistan* (34%), *Nepal* (32.1%), *Bangladesh* (6.5%), *India* (5.2%), *China* (4.7%) (WTO, 2013a).

In the market of garment products, *Asia*'s dominance is significant and equally trades globally. *Europe* operates a more closed, 'indoor' market—80% of products are traded within its boundaries; only a small number is exported to, among others, *Asia* (5.6%), to the *former Soviet Republics (Commonwealth of Independent States)* (5.3%), and to *North America* (3.6%) (WTO, 2013b). In the American continent, *Central America* (especially *Guatemala*) plays a key role which is leading the regional cloth production and 66% of their items are exported to the *North American* markets. The global garment products in the export of the overall industrial sector represent a significant share in *Haiti* (88.3%), in *Bangladesh* (79.4%), in *Cambodia* (52.4%), in *Sri Lanka* (42.7%), and in *Vietnam* (12.3%). Compared to the year 2000, the production in *Vietnam* had increased by seven times, in *Cambodia*, *China* and *Bangladesh* four times, and in *India* two times by the year 2012 *(Table 1)*.

Table 1 – Clothing exports of selected economies, 1990–2012
Source: WORLD TRADE ORGANIZATION (2013a; b)

	Value (Million dollar)					Share in economy's total merchandise exports (percentage)	
	1990	2000	2010	2011	2012	2005	2012
Cambodia	...	970	3,041	3,995	4,294	71.5	52.4
China	9,669	36,071	129,820	153,774	159,614	9.7	7.8
Bangladesh	643	5,067	14,855	19,213	19,948	74.1	79.4
India	2,530	5,965	11,229	14,672	13,833	8.8	4.7

Figure 1 – Countries included (shaded areas) in this paper in order of discussion: Vietnam, Cambodia, Bangladesh, India, Pakistan, Nepal and China
Edited by BOKOR, L. with P&P WORLD MAP (2015)

Based on these statistics, the textile industry's impact on the environment defines two main categories for the countries analysed: first of all, the countries with high export value—*China*, *India*, *Pakistan* and

Bangladesh (Figure 1). Secondly, the industrialising countries with no significant previous textile and garments industry—*Vietnam*, *Cambodia* and *Nepal (Figure 1).* In the next chapters, these counties will be analysed as *Asia*'s weight in the global market as the most significant.

4.1. Vietnam

The most interesting example is *Vietnam*'s. In this *Asian* country, despite the changing economic factors, a significant growth rate can be identified. The leading products are knitted items, for example jerseys, jumpers and shirts. According to the production's regional division, the *Northern Region* (*Hanoi*, *Hung Yen*, *Hai Duong*, and *Nam Dinh*) shares 30%, the *Central Region* (*Thua Thien Hue*, *Da Nang* and *Khanh Hoa*) 7%, and the *Southern Region* 63% (DANG, T. D. *et al.* 2010). In the northern areas, due to the lack of infrastructure, the industry has been developed around or near the large settlements which also minimises the time between orders and productions. Vietnamese companies favour small or medium size business orders, and the extended production deadlines guarantee the better quality final products and also the continuity of workload. The main trading partners are the *United States of America (USA)* (60%), the *Europe Union (EU)* (12%), *Japan* (11%) and *Canada* (3%) (VIETRADE, 2014). A steady growth may be observed in the *USA* and the *EU*. From an environmental point of view, the textile factories settled in the *Northern Region*'s industrial parks combine modern, complex fibre producing, knitting, dyeing and sewing processes: for example in the *Dinh Vu industrial park* in *Hai Phong* (KONSTADAKOPULOS, D. 2008).

In the case of *Vietnam*, the most threatening problem is water pollution caused by their decentralised production structure; the small factories' principal reason for this is that the wastewater is without purification let straight into the environment, mainly to wetlands. This causes severe problems in fishing, and on the rivers' lower sections, agriculture—especially rice production and fish farming—which is heavily impacted by it.

4.2. Cambodia

Cambodia's geographical situation, physical conditions and environmental issues are very similar to *South Vietnam*'s. However, their social and economic development are significantly different as the very cheap Cambodian labour provided a quick grow rate and space for the textile industry. In the medieval times, Cambodian 'golden' silk was world-renowned, but the centuries-old tradition was almost fully exterminated by the *Khmer Rouge*; therefore, the necessary basic materials have to be imported from *China* and *Thailand*. It makes the advance more advantageous that the country has a quota-free access to the *North American* and *European* markets. Among the foreign investors, primarily the large manufactures moved their factory plants to *Cambodia*, for example *China* (121 million USD), *Taiwan* (112 million USD) and *South Korea* (70 million USD) have invested in the local production (CLAUDIO, L. 2007). This is the only country where the labour norms are supervised autonomously by the *International Labour Organization (ILO)*. Thanks to the *Better Factories Cambodia (BFC)* programme, the *USA* gradually opens a wider market space for the country (MERK, J. 2012).

4.3. Bangladesh

Based on the ILO (2012) statistics, the share of textile production in *Bangladesh*'s export represented 79.4%—which is the highest rate in the world. According to the rapid industrialisation, the worst environmental problems occur in this country, majorly because the environmental rules are entirely ignored.

Bangladesh is one of *Earth*'s most significant wetland regions, and the *Ganges Delta* together with the coastline of the *Bengal Bay* are heavily populated. The low-lying land areas are constantly threatened by frequent transgressions caused by climate changes which dramatically affects the productivity of agriculture. This problem is aggravated by the toxic unpurified water let straight into the rivers by textile factories. The situation is extremely serious in the vicinity of *Dhaka* where the heavily concentrated factorial wastewater is accumulating in canals and lakes. The government authorities only deal with environmental protection

and sustainability at administrative level which does not manifest in practice (AHMED, T. – TAREQ, S. M. 2008). The degree of contamination caused by the textile industry is well indicated by the coconut trees, thus their productivity is heavily decreasing due to their exposure to a constant bombardment of pollutants. *Dhaka* and the *North Central Region* contribute to half of textile production which includes predominantly ready-made garments and leather products. Accordingly, the environment around *Dhaka*, especially the *River Turag*, is the most contaminated areas in *Bangladesh*; the by-products of the textile dyeing, tanning and dressing of leather processes (copper, cadmium, lead, and chrome) have the most significant environmental impacts (MIA, C. M. 2001).

At present, the most challenging is to keep the textile industry producing competitively whilst moving towards the usage of environmentally friendly dyes and chemicals which would reduce the burden of pollution on the environment and provide better energy efficiency as well. Also, the modernisation of production technologies, the introduction of biological and photochemical treatment of wastewater, and advanced ion-exchanger and membrane filter equipment would be a key task. The textile industry is a 'double-edged sword' in the country's existence, because this is what pulls the overall industrial production which therefore improves the standard of life. By the co-operation of research and development institutions (R&Ds) founded and funded by governmental support, along with the involvement of local communities and also by the expansion of trainings, *Bangladesh* will only be able to reduce significantly or stop further environmental contamination.

4.4. India

India's biggest 'employer' is the textile industry where there is about 35 million people working (5.2% in 2012 within the total industrial export) and being involved in the industrial production. In the agriculture closely connected with the textile industry gives job to another 93 million employees. In the production, 70% represents cotton, 20% goes to the synthetic materials, and about 10% is silk, wool, jute and coir. The ready-made products are then principally exported to the *USA*, the *EU*,

Japan and *Hong Kong*. It plays a leading role in the production and trade of quality basic materials which influences the contamination of air, water and soil, but it has effects on the society, too. The production processes are mainly concentrated in factories around the large cities; overall there are 1400 textile factories and 280 synthetic fibre producers in operation in *India* (CHAVAN, R. B. 2001). These plants as spot-like pollution sources technically cover every area of the country. Their concentration can be observed along their industry-essential water resources. *Kolkata* on the coastline of *Bengal Bay*, and *Kanpur* along the *River Ganges* are the biggest centres of textile industry. On the *Western* side of the *Indian subcontinent*, *Mumbai* and *Ahmadabad* represent the classic, large textile centres (BOKOR, L. – SZELESI T. 2011).

The cotton industry's odorous discharged materials (for example sulphur for dyeing, sodium hypochlorite for whitening) make it unbearable for plant/crop growth in heavily urbanised living spaces. The sector's biggest problem is represented by the non-biodegradable materials which are not used in production, but during maintenance (for example machinery). The treatment of wastewater left after the dyeing process is the easiest, but by the modernisation of the technological processes and the reorganisation of them, a significant result could be achieved (HAYDAR, S. – BARI, A. 2009). The *Indian Government* has stated that it is in favour of tightening the environmental regulations and the compliance with international norms by which in the last few decades they have been able to displace almost entirely the carcinogenic substances from the production processes. This process started off in 1996 by an external pressure when *Germany* and *the Netherlands* prohibited the trade of garment products in a wide spectrum. In present days, international organisations (among others for example *MST–German Textile Association*; *OTN–Ökotex Institute of Austria*) define, evaluate and grade the manufacturing processes which is also supported by the *Indian Government* (CHAVAN, R. B. 2001). Materials produced in an environmentally friendly way are denoted by a new symbol (earthen pot, also known as 'matka'); the ecomark makes it clear for the consumers from where the product comes.

4.5. Pakistan

The *River Indus* and its tributaries, in a clearly demarcated region, concentrate the textile industry of *Pakistan*. The largest centres are *Islamabad*, *Faisalābād*, *Lahore*, *Multān* and *Karachi*. The wide spectrum-forced manufactory shares a significant piece in the environmental contamination, but the transport and the agriculture that consume chemicals without measure cause similar damage. *Karachi* registers nearly 6000 industrial producers who give 60% of the country's total production (TECHNOLOGY TRANSFER FOR SUSTAINABLE INDUSTRIAL DEVELOPMENT, 1995). This makes the environment specialists face extreme challenges, thus the producers at the coastline of the *Arab Sea* together with the pollutants from the source of the *Indus* are collectively threatening the habitats and wildlife reserves (AMJAD, N. 2011). The crisis situation is well indicated by the extinction of shrimps from the coastal waters. The textile industry within the entire industrial production represents 35.4% which is a significant downfall since the year 2000 when it was at 60%. The biggest basic material production is yarn manufactory which is used by the spinning industry where there are about 200,000 people in work. The woven fabric industry uses the domestically produced cotton and synthetic filaments and employs about 300,000 workers, whilst the biggest sectors and employer is the garments manufactory that counts over 700,000 employees. Among the production processes such as whitening, dying and printing are the main causes for water pollution which are dramatically reducing the water's *Biological Oxygen Demand* (BOD), increasing its pH level, and releasing oils and fats (MALIK, A. F. 2002). Similarly to *India*'s case, the majority of the *European* countries have banned the azo dyes which forced the modernisation of textile industry, the *ISO 9000* and *14000* quality management standards systems have been applied and are used by 290 companies which represents 80% of the total industrial producers (MALIK, A. S. 2002).

4.6. Nepal

Nepal is a specific case in the geographical neighbourhood of textile producing giants. A traditional branch of industries is textile spinning which

basis is formed by the small and backyard entrepreneurships. The old manufacturing methods and procedures can basically be considered environmentally friendly; however, regarding their basic materials, they rely on products imported mainly from *India* and *China*. The neighbouring countries can produce their items 25–30% cheaper than the traditionally based Nepalese spinning industry. Due to this reason, the imported clothing items have been gradually increasing in the market (SHAH, B. 2002). According to the effects on the market, 60% of the medium size industrial plants have recently been closed down, the productivity of the rest in operation is about 30%—which has had a positive benefit on the battle against environmental pollution (YADAV, I. C. *et al.* 2014). On the world market, pashmina—which is the finest type, light and warm knit wear made from the wool of cashmere goats—has achieved great popularity, and the cotton terry towels represent 88.9% of the export products. With *China*'s help, two synthetic fibre plants were established in 2002 which, from an environmental point of view, are modern and provide additional locally produced basic materials. Because the country is situated in high mountain regions and it does not have large volumetric flow rated rivers, the bases of textile industry are provided by groundwater reserves—which are seriously threatened by the discharge of heavy minerals, bleaches and whiteners (BRITISH GEOLOGICAL SOCIETY, 2001).

4.7. China

In *China* around 50,000 textile factories are contributing to 34% of the world's textile, and 38% of garment products. The export is shared by 62% of knitted goods, 31.5% of woven products and 6.5% of synthetic fibre. The textile industry's geographical situation is significantly affected by the access to water resources; thus along the *Huang He*, *Chang Jiang (Jangce)* and their tributaries, and along the shoreline of *South China Sea* are concentrating most of the factory units. Inside the country, business districts have been developed for the production and trade of a variety of goods; thus concentration of the fabrics are in the southeast,

the garment items and their complements are in the northeast, the company oriented international trade are in the central east, and the basic material market is in the west.

The centralised environmental protection does not encourage sufficiently the producers to implement new technologies (LUONG, V. H. – UNGER, J. 1998). By investments with a 5-year recovery period, the ecological footprint of the textile industry could be decreased, but the competition among companies and the voracious greed for profit entirely push the green thinking in to the background. In the government's 9th and 10th five-year plans there are serious aspirations to supply the textile and garment industry with modern machinery. There have been four categories implemented to support new investments: supported, permitted, restricted and banned. A supported method or project is which

- applies the newest R&D technologies from the production of raw materials via processing to the ready-made goods production,
- saves a significant amount of energy,
- increases the quality of the produced goods,
- in a comprehensive way utilises raw materials and by-products.

A restricted method or project is which

- uses obsolete technologies,
- does not benefit to the environment and support sustainable raw material economy,
- has come in existence for manipulative purposes.

A banned method or project is which

- means a risk to the national security and it is a potential hazard to the public interest,
- pollutes the environment and weakens the general health of people,
- threatens the market of traditionally crafted goods.

In the permitted category goes everything that does not fit in any of the other three (RUPP, J. 2010).

5% of the *Chinese* electricity consumption is billed to the textile industry which means a significant amount of CO_2 emission and air pollution. For the majority of water utilisation and wetland contamination

the textile and garment industries are responsible; the unpurified waste water may cause sever and irreversible damage in the environment. The conventional and obsolete technologies *China* has also exported to countries with poor environmental regulation and lack of sustainable actions (for example *Cambodia*, *Laos*, *Bangladesh*)—profit and economic growth has enjoyed privilege (EUROPEAN COMMISSION, 2005).

Asia plays a significant role in the world's textile industry where each country specialises in a different product category and, therefore, each has certain environmental issues. Profit centred large companies do not take into account the norms of sustainability, any development of technologies, more or less, happens only by external constrains.

Positive change is that several countries have applied to emerging, environmentally friendly and holistic technologies including the use of natural ingredients, raw materials and colours (dyes). The R&D sector plays a key role in the management of industrial wastewaters which helps preventing an extensive environment degradation.

In the next section, the processes textiles go through in factories from crop to finished product and how many different production processes effect the environment will be explained. The majority of people may not even realise such productions are involved when it comes to creating a simple cotton T-shirt for example. When referencing textiles in this section of the essay, the authors are specifically looking at clothing, focusing on cotton which is one of the most popular materials for making fabrics from. Of course there are many raw materials that clothes can be made from, but here cotton is discussed because of its huge production process from crop to clothes and how this process stresses and strains our living environment from multiple directions.

5. The methods of cotton textile production that effect the environment

To begin with, cotton is usually grown in tropical/subtropical regions of the world such as *Africa* and *South Asia* (for example *India*). To grow the

crop it takes plenty of sunshine and just a little rainfall to supply a sufficient cotton crop. The first environmental impact for both the crop and other living elements are the pesticides used in the cotton fields (RIELLO, G. 2015). Herbicides, fertilisers and insecticides are heavily relied on by cotton farming industries, causing considerable damage to other natural wildlife surrounding the fields. The chemical pollution absorbed into the land itself can then pass into streams and rivers. Nitrogen fertiliser, for example, can be 300 times more potent than CO_2 depending on the factory it has been produced in and the efficiency of the farmer spreading it across the fields (BERNERS-LEE, M. 2010).

Next is the harvesting of the cotton. Today the cotton crop is harvested by machines that pick the crop without damaging the cotton boll itself. Of course cotton is still picked by hand today which brings many ethical issues into this process; however, we have chosen to concentrate on the machine harvesters as they contribute to the overall environmental impact of this textile production. The harvesters need fuel that subsequently burns into the atmosphere contributing to the high CO_2 levels produced by petrol and diesel vehicles every day. Further fuel is then needed for transport vehicles to take the harvested cotton bolls to factories that prepare the crop to be transported again to a mill. There are many elements within the factories themselves that contribute to environmental damage. For example, these factories heavily rely on fossil fuels for their energy needs, the burning of which not only contributes to more CO_2 levels, but other environmental concerns such as noise, heat, smell (from fumes and smoke) and light pollution. All these play a role within textile production and the depletion to the environment. (MURTHY, M. S. S. 2001; UTIACOMM, 2011).

The next step is the production of cotton in the mill. There are several processes inside the mill itself. To begin with you have the machine that separates the cotton from any debris such as grass, stones, mud and stalks. It is then funnelled into a compressor to extract cotton oil which is commonly used in all types of food from potato crisps to salad dressings. The cotton is compressed into bails and packaged to be delivered to factories all over the world via multiple forms of transport (UTIACOMM,

2011). Some modes of transport like flying on a plane for example is worse than driving a transporter truck when it comes to CO_2 levels. And of course we have to think of the fuel usage by these modes of transport, how well the vehicles perform and other factors for road vehicles such as traffic. For example, driving a truck in a traffic jam can cause three times the emissions than a clear drive on the same road. (BERNERS-LEE, M. 2010). As we can see, the cotton has gone through a huge environmentally damaging process already and it is still only in its raw form.

Once at the mill, the cotton is put into a cleaning machine which processes half a tonne of cotton per hour—we will go into more detail on the environmental effects of the 'washing' process in textiles later. The raw cotton is in fact cleaned twice before being taken to the carding machine which acts as a giant comb to untangle the cotton fibres. A coiler than gathers up the untangled fibre and creates thick strands to then be threaded through a roving frame which thins out the cotton to create the typical cotton thread we recognise today. A typical Bangladeshi warehouse running on coal or gas power producing textiles from cotton will process 1 tonne of cotton which needs 65,000 kWh of electricity and 250,000 litres of water. Three-quarters of that water is used in the 'wet' treatment which includes the washing, dyeing and rinsing processes (PUMPKIN INTERACTIVE, 2011).

Further equipment and machinery is used to wind the yarn on to spools. There are a variety of methods and automated machinery that create these spools all of which require a huge amount of energy to run. On average it takes around forty-eight hours for the cotton to be spun—from the moment it is put into the cleaning machine in its raw state to it being processed and spun tightly onto the spool (COLLIER, I. 2009). This means the factory would be running constantly, as soon as one process ends, another one begins. In 2008, yearly worldwide textile production was estimated at 60 billion kilograms of fabric. The estimated energy and water needed to produce this was estimated at 1,074 billion kWh of electricity or 132 million metric tons of coal and between 6–9 trillion litres of water (RUPP, J. 2008).

The spools are then packaged and transported again to the factories where giant looms process the threads into recognisable textiles. Sometimes the cotton threads are put through a starching process which strengthens the fibres, but also involves a considerable amount of heating for the cotton to absorb the starch efficiently. The looms then take over, weaving the cotton into huge sheets of fabric. The looms alone are incredibly noisy and factories will sometimes have over 200 looms in a single space all working simultaneously to produce the fabric. A considerable amount of dust from the cotton fibres litters the factory floor and machinery resulting in machinery break down, hazard to human health and environmental damage if not disposed of properly. The finalised fabric is then transported to factories where they complete the singeing process. This process involves the fabric being scoured, peroxide bleached and dyed different colours (LAP QUILTING WITH GEORGIA BONESTEEL, 2014)—the bleaching/dying process we will look at in more detail later. It is then further washed at 80°C on a continuous roll and then rinsed in more water at 30°C. The fabric rolls are then dried in a fabric 'oven' at 200°C and then packaged to be sent to clothing factories (COLLIER, I. 2009). So far, everything we have discussed is, of course, based on an average textile factory and its processing needs, but all manufactories differ in machinery use, the degree of energy utilisation and, therefore, production.

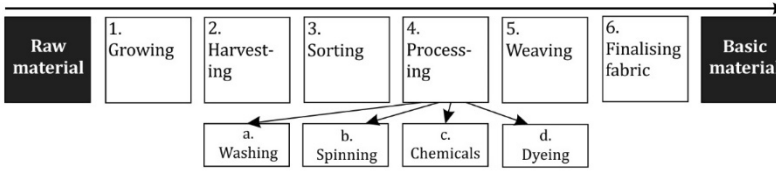

Figure 2 – The route of cotton from raw material to basic recognisable fabric

Designed by BOKOR, L. – ECCLESTON, K. (2015)

6. The most environmentally damaging processes in the production of cotton

This section will look at three processes that cotton goes through in a factory which have been described in the previous chapter, and looks at the extended environmental impacts of discussed process. These processes are (*a*, *c* and *d* in *Figure 2*):

- dyeing,
- washing/rinsing,
- chemical use.

First is the dyeing process which begins inside the factory, but causes catastrophic harm outside of the factory environment to humans, animals/insects, the land and to water resources. The second is the washing and rinsing process which uses unbelievable quantities of water often getting thrown away and pumped out into the outside world. The third process is chemical use. Chemicals begin in the fields when the cotton crop is growing, but in the factory further chemicals are used to strengthen and coat cotton fibre resulting in small amounts of toxins being released when wearing or using the material form and the inability for the fabric to degrade. After, how each process can be improved through alternative environmentally friendly methods, such as natural dyeing and eco farming, will be shortly overviewed.

6.1. Dyeing

Dyeing is the process of colour being absorbed into a materials fibre for a permanent aesthetic change. Natural dyes can be made from food stuffs such as berries, a variety of vegetables, plants and nuts. It can be made with flowers, roots, wood, mineral sources and small animals such as insects. Synthetic dyes are based on particular types of chemical compositions. Some of these include acid dyes such as anionic dye and neutral dyes like sulphur dye, vat dye, pigment dye and reactive dye.

There are many ways to dye fabric depending on what the material is made from. The most common way of dyeing cotton is with synthetic dyes by a process called ‘direct dyeing.’ This is when the dye is added

directly to the fabric without any other agents such as affixing chemicals or stabilisers. Synthetic dyes are most commonly used on cotton because they are highly soluble and react best to the cotton fibre (TE-ONLINE, N.A.).

There are many different dyeing machines used in factories which all require a continuous power supply to run efficiently, however, the type of machine in this case is not our focus. All these machines need to have heating facilities to heat the dyes up to temperatures that are near boiling point, meaning extra power is needed to keep these temperatures up at a continuous rate. One of the most common machines is a batch process where the fabric is fed through a concentrated chemical pool on a roller with the extra appliance of heat and steam. Each time a fabric is passed through a solution, an amount of water equivalent to the weight of the fabric must be used (CHEQUER, F. M. D. *et al.* 2013).

The biggest problem with the dyeing process of textiles is the disposal of the left over dyeing water/effluent after it has been through the machines and fabric. It has been calculated that approximately 200 litres of water are needed for each kilogram of cotton produced and that 10%–50% of the dyes used in the dyeing process are lost ending up in the disposed water or in toxic sludge waste (CARNIERO, P. A. *et al.* 2007; CHEQUER, F. M. D. *et al.* 2013).

There can be as many as 2000 chemicals used in a textile dyeing process, many of them highly toxic to human and animal life. The textile industry is the number 1 biggest industrial polluter to our fresh water sources (O TEXTILES, 2011a). *Bangladesh's* textile industries produce around 56 billion litres of contaminated water a year, enough to fill twenty two and a half thousand Olympic sized swimming pools. Three-quarters of this water is used during the 'wet process', which is the dyeing, washing and rinsing. (PUMPKIN INTERACTIVE, 2011). *China* however has the most polluted waters due to their industry wastage. Half of *China*'s water is classed as unsafe for humans with 70% of rivers, lakes and reservoirs being polluted (GREENPEACEVIDEO, 2011). Wastage from a textile factory for example will discharge their waste water (often different colours from the dye stuff) straight into local rivers and seas.

"Today the water is red and tomorrow it could be green…that's how it is!"

(Textile factory worker. Hangzhou, China.) (GREENPEACEVIDEO, 2013)

People who live and work near the factories accept 'that's how it is'. They are living with dangerously high levels of pollution in both drinking and washing water, with local farmers and fisherman losing their businesses as the polluted waters will kill all crops and water life such as fish and crab. The dyes from these factories not only colour the waters but also human skin. It is not uncommon for a typical factory worker to finish work and be covered from head to toe in dye powders. The dye stains your skin that no amount of washing can remove, eventually (after several months) it only begins to fade. Workers have even reported their saliva changing colours because of these dyes. If this with the amount of dye powder is combined with fibre particles and other chemicals present in the factory environment, it is not surprising that long term diseases and cancers are becoming more and more common amongst factory workers and those living locally to the factories also (GREENPEACEVIDEO, 2013).

6.1.1. Environmentally friendly dyeing

Air dyeing technology is an alternative to typical dyeing methods that mainly use water. On average air dyeing process can use (depending on the type of fabric) 95% less water, and 87% less energy in its process and emits 84% less *Green House Gases (GHG)* (KANT, R. 2012). Air dyeing works by heating up fabric, then injecting dyes straight into the fibres in the form of a gas. Unfortunately air dyeing can only be used on synthetic fibres, so the need to reduce water and chemical dyeing consumption in cotton and other natural fibres remains an ongoing problem to solve (UPHAM, B. C. 2009).

6.2. Washing/rinsing

The washing/rinsing process is the biggest cause of water consumption in textile production during the wet treatment. As mentioned earlier in

section 5, in 2008 the yearly worldwide textile production for water was between 6–9 trillion litres with some 17–20% of industrial water pollution coming straight from textile wet treatments (KANT, R. 2012).

In *section 5.1* the dyeing process was discussed and understood as dye stuffs including many hazardous chemicals such as mercury, nickel, arsenic and lead, resulting in water being polluted with toxic effluent. These chemicals including many others, give the waste water a foul smell and unpleasant appearance. According to KANT, R. (2012), *"This in turn interferes with the oxygen transfer mechanism at air water interface" which then effects "marine life and self-purification".*

Water is not only required for dyeing but for further washing and rinsing of finished fabrics. Dyeing however can contribute to 15–20% of the total water used in wet treatments (KANT, R. 2012). Further chemicals are used in the washing process such as caustic soda soaps and enzymes. More water is then needed to clean the machines themselves as the build-up of dye powder and soap scum can affect the machinery's overall performance resulting in break downs and inefficient running.

One of the worst effects on water caused by textile wet treatments is the depletion of oxygen in the water itself. This results in no marine life in nearby waters surrounding the local textile factories. Factories will often discharge of their waste water at night (as not to get caught by environmental officers) straight into rivers, the sea and into human water resources. Such polluted waters may not be able to host marine life but they can be a breeding ground for bacteria and viruses. *"Some 72 toxic chemicals have been identified in water solely from textile dyeing, 30 of which cannot be removed"* (KANT, R. 2012).

Another serious issue with polluted water from textile factories is the waters resistance to disinfectant. Carcinogens such as chlorine react with disinfectant making it impossible to treat the waste water. Chlorine is also known to have serious side effects to human health when inhaled or absorbed by the skin (KANT, R. 2012).

6.2.1. Improving the textile industries' water consumption

To help the wastage of water, using less in the manufacturing and reducing the steps in the wet treatment process could be beneficial in reducing large water quantities (SLATER, K. 2003). Also, by reducing waste, this could not only help the environment but also prove cost effective to the manufacturers due to using less water and recycling left overs.

Reducing and recycling water are the only ways factories will be able to effectively control their water consumption. Water is of course necessary in textile production but by reducing all forms of waste, industries could save between 20–50% expenditure on water with further appropriate water recycling methods saving even more money. For example, waste water could be recycled and used for cleaning machinery and other areas of the factory (KANT, R. 2012).

FREY, F. – MEYER, M. (1996) describe an oxidation reactor that could treat polluted waters and reduce consumption water and chemicals in the process. The benefits of this is that it could convert up to 90% of waste water into carbon dioxide and water, as well as saving 80% of water and 20–30% of chemical use.

Textile industries use many waste water treatments, but unfortunately water can only be re-used effectively if it is free of chemicals. Next, chemical use and their damaging effects on the environment will be discussed in more detail.

6.3. Chemical use

Chemical use initially begins in the fields of the cotton crop through the use of herbicides and insecticides, but in this section we are just focusing on chemicals used in factory processes on textiles themselves. As discussed in *sections 6.1.* and *6.2.* many, many chemicals are used throughout the wet treatment process and here we will look at the main effects these chemicals have on the environment.

Chemical use is of course crucial to fabrics being hard wearing and longer lasting. It is far better for a consumer to keep and re use a T-shirt for 5 years, than to throw away and buy a new one every year. However, the chemicals stored in the fibres of fabric today are making it harder

for these textiles to degrade. For example, non-bio degradable and formaldehyde based dyes result in textiles being so preserved that they fail to degrade when placed in land fill (KANT, R. 2012). Formaldehyde is often used as a finishing element to a textile, helping to resist staining and improve waterproofing. The formaldehyde can contain releasing preservatives when the textile is under such pressures as heat from ironing or outside temperature, resulting in the person wearing them to inhale and/or absorb the preservatives through the skin (O TEXTILES, 2011b). Not only does this chemical have damaging effects to human health but to the environment as well. Many companies will disguise the name 'formaldehyde' with names such as methyl aldehyde, methylene oxide, oxymethylene and oxomethane. When these chemicals are disposed of as wastewater into surrounding areas, they are absorbed into the land, resulting in contamination of soils and vegetation. They eventually make their way into water resources destroying aquatic life and polluting human drinking water. These chemicals are pumped out as wastewater often at high temperatures from the wet treatment process, which can cause change in the chemicals themselves, realising fumes into the air and permanently contamination the water (KANT, R. 2012).

6.3.1. Reducing chemical use in textiles

It is unlikely that chemical use is going to be prohibited completely when it comes to the production of textiles. However, standards and controls are currently in place to help limit the use of common chemicals. For example, *GOTS (Global Organic Textile Standard) "is a tool for an international common understanding of environmentally friendly production systems and social accountability in the textile sector"* (O TEXTILES, 2011b). GOTS covers a wide area of textile production, particularly in the use of certified fibres, the banning of genetically modified organisms (GMO) and also the prohibition of many chemicals, including formaldehyde. GOTS claim that, *"only textile products that contain a minimum of 70% organic fibres can become GOTS certified (a textile product carrying the GOTS label grade 'organic' must contain a minimum of 95% certified organic fibres whereas a product with the label grade 'made with*

organic' must contain a minimum of 70% certified organic fibres) and all chemical inputs such as dyestuffs and auxiliaries used must meet certain environmental and toxicological criteria" (GOTS, 2014).

7. Conclusion

Through the putting together and researching of this article, many issues between textile production and its effects on the environment have been highlighted, the majority of which have the capability for further research to be carried out and other articles to be written. Our focus has been on *Asia* and its significant role in the textile industry. The countries mentioned all work towards a large amount of textile production which therefore has individual environmental issues that need to be addressed. Profit centred large companies do not take into account the importance of sustainability, with any development of technologies happening by external constrains. Several countries have adopted environmentally friendly and holistic technologies including the use of natural ingredients, raw materials and dyes with the R&D sector playing a key role in the management of industrial wastewaters, helping to prevent an extensive environment degradation.

A description of cotton, from crop to finished fabric, highlighted the multiple processes a material is put through, including the damaging effects these processes have and still are causing to the environment. Irreversible damage has been done through the use of poisonous chemicals and dyes, and the factories still burn away at our fossil fuels as a source of their power. However, through new technologies such as air dyeing and steps introduced to ensure water is recycled and reused efficiently, further damage to the environment around the textile factories can be minimised and monitored.

References

AMJAD, N. – SHAHID, L. A. – AHMAD, T. – KALWAR, S. A. (2011): *Agricultural Mechanization in Pakistan: ABEI Contributions.* Proceedings of the International Seminar on Role of Agricultural Machinery on Poverty Alleviation and Food

Security in Pakistan, held at University of Agriculture, Faisalabad, pp. 71–78.

BERNERS-LEE, M. (2010): *How bad are bananas?: The carbon footprint of everything*. – Profile Books, London, p. 107; p. 138.

BOKOR, L. – SZELESI, T. (2011): *Európán kívüli gazdasági centrumok regionális földrajza.* – Pécsi Tudományegyetem Természettudományi Kar, Pécs, pp. 63–68.

CARNEIRO, P. A. – PUPO NOGUEIRA R. F. – ZANONI, M. V. B. (2007): *Homogeneous photodegradation of C.I. Reactive Blue 4 using a photo-Fenton process under artificial and solar irradiation.* Dyes and Pigments, Volume 74, Issue 1. – Elsevier, pp. 127–132.

CHAVAN, R. B. (2001): *Indian textile industry – Environmental issues.* Indian Journal of Fibre & Textile Research. Volume 26., March–June – Indian Institute of Technology, pp. 11–21.

FREY, F. – MEYER, M. (1996): *Cracking industry's wastewater challenge.* America's Textiles International, Volume 25, Number 11., pp. 56–58.

HAYDAR, S. – BARI, A. (2011): *Characterization and study of correlations among major pollution parameters in textile wastewater.* Mehran University Research Journal of Engineering & Technology, Volume 30., No. 4. – University of Engineering and Technology, Lahore (Pakistan). Dept. of Environmental Research, pp. 577–582.

KANT, R. (2012): *Textile dyeing industry an environment hazard.* Natural Science, Volume 4. Number 1. – Scientific Research, pp. 22–26.

KONSTADAKOPULOS, D. (2008): *Environmental and resource degradation associated with small-scale enterprise clusters in the Red River Delta of northern Vietnam.* Geographical Research, Volume 46., Number 1., p. 51.

LUONG, V. H. – UNGER, J. (1998): *Wealth, power, and poverty in the transition to market economies: The process of socio-economic differentiation in rural china and northern Vietnam.* The China Journal 40. – pp. 61–93.

MERK, J. (2012): *10 Years of the Better Factories Cambodia Project*. – Clean Clothes Campaign & Community Legal Education Centre, p. 38.

MIA, C. M. (2001): *Assessment of effluent quality of Dhaka export processing zone (DEPZ, old) with special emphasis on textile and dye industries*. MSc Thesis Department of Chemistry – Jahangirnagar University

MURTHY, M. S. S. (2001): Never say dye: The story of coloured cotton. Resonance, Volume 6, Issue 12. – Springer, pp. 29–35.

RIELLO, G. (2015): *Cotton: The Fabric that Made the Modern World.* – Cambridge University Press; Reprint edition, 436 p.

SHAH, B. (2002): *A Study on Textile and Clothing Sectors in Nepal*. Nepal's Accession to World Trade Organization Project. – HMG Ministry of Industry, Commerce and Supplies, United Nations Development Program (UNDP) & United Nations Conference on Trade & Development (UNCTAD), 59 p.

SLATER, K. (2003): *Environmental Impact of Textiles (Woodhead Publishing Series in Textiles)*. – Woodhead Publishing Ltd, Cambridge, 240 p.

TECHNOLOGY TRANSFER FOR SUSTAINABLE INDUSTRIAL DEVELOPMENT (1995): *Environmental examination of the textile industry in Pakistan*. – Sustainable Development Policy Institute Islamabad. Report no. Z5CR1TT1

YADAV, I. C. – DEVI, N. L. – MOHAN, D. – SHIHUA, Q. – SINGH, S. (2014): *Assessment of groundwater quality with special reference to arsenic in Nawalparasi district, Nepal using multivariate statistical techniques.* Environmental Earth Sciences, Volume 72, Issue 1. – Springer, pp. 259–273.

Electronic sources

AHMED, T. – TAREQ, S. M. (2008): *Textile Industries In Bangladesh: A Rising Environmental Degradation Down The Drains.* Textile Today [online]. Available at <http://www.textiletoday.com.bd/textile-industries-in-bangladesh-a-rising-environmental-degradation/> [Accessed 10 November 2015]

BRITISH GEOLOGICAL SOCIETY (2001): *Groundwater quality: Nepal.* Wateraid [online]. *(pdf)*. Available at <http://www.wateraid.org/~/media/Publications/groundwater-quality-information-nepal.pdf> [Accessed 14 November 2015]

CHEQUER, F. M. D. – DE OLIVEIRA, G. A. R. – FERRAZ, E. R. A. – CARDOSO, J. C. – ZANONI, M. V. B. – DE OLIVEIRA, D. P. (2013): Chapter 6: *Textile Dyes – Dyeing Process and Environmental Impact*. In: GÜNAY, M. *Eco-Friendly Textile Dyeing and Finishing*. Intech [online]. Online open source article. Available at <http://www.intechopen.com/books/eco-friendly-textile-dyeing-and-finishing/textile-dyes-dyeing-process-and-environmental-impact/> [Accessed 14 November 2015]

CLAUDIO, L. (2007): *Waste Couture: Environmental Impact of the Clothing Industry.* US National Library of Medicine National Institutes of Health [online]. Environmental Health Perspectives 2007 Sep; 115 (9): A449–A454. Available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1964887/> [Accessed 14 November 2015]

COLLIER, I. (2009): *How It's Made Fabrics.* YouTube [online]. *Video file*. Available at <https://www.youtube.com/watch?v=YYWlevX7Kw0 > [Accessed 15 October 2015]

DANG, T. D. – MAHANTY, S. – THANH VAN, N. (2010): *Vietnam's craft villages and water pollution: A review of previous research.* Crawford School of Public Policy, ANU College of Asia & the Pacific [online]. *(pdf)*. Australian National University Canberra. Available at <https://crawford.anu.edu.au/rmap/pdf/_docs/water_pollution_craft/dang_et_al_2010.pdf> [Accessed 11 November 2015]

EUROPEAN COMMISSION (2005): *Study on China's Textiles & Clothing Industry and its Market Expansion Strategy.* European Commission [online]. *(pdf)*. Available at <http://trade.ec.europa.eu/doclib/docs/2005/december/tradoc_126633.pdf> [Accessed 14 November 2015]

GLOBAL ORGANIC TEXTILE STANDARD – GOTS (2014): *The Standard – General Description.* Global Organic Textile Standard [online]. Available at <http://global-standard.org/the-standard.html> [Accessed 22 November 2015]

GREENPEACEVIDEO (2011): *Detox: Dirty Laundry background - September 2011 update.* YouTube [online]. *Video file*. Available at <https://www.youtube.com/watch?v=llpesURtaKs> [Accessed 28 September 2015]

GREENPEACEVIDEO (2013): *Textile Towns in the Shadows of Pollution.* YouTube [online]. *Video file*. Available at <https://www.youtube.com/watch?v=KdrHIAISsvA> [Accessed 28 September 2015]

ILO (2012): *Decent Work Country Programme 2012.* ILO [online]. *(pdf)*. Available at <http://www.ilo.org/public/english/bureau/program/dwcp/download/bangladesh.pdf> [Accessed 17 November 2015]

KALBERLAH, F. – SCHWARZ, M. (2011): *Substances classified as carcinogenic, mutagenic and toxic for reproduction (CMR) and other substances of concern in consumer products. Identification of relevant substances and articles, analytical control and consequences for the regulation of chemicals – Summary.* Umwelt Bundes Amt [online]. *(pdf)* Umwelt Bundes Amt – Für Mensch und Umwelt, 27 p. Available at <https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4092-0.pdf> [Accessed 8 December 2015]

LAP QUILTING WITH GEORGIA BONESTEEL (2014): *Episode 403 "From Field to Fabric".* YouTube [online]. *Video file*. Available at <https://www.youtube.com/watch?v=h3lTeG3tHF8> [Accessed 28 September 2015]

MALIK, A. S. (2002): *Impact of Environmental Regulations on the Textile Sector of Pakistan.* UNCTAD – United Nations Conference on Trade and Development [online]. Country Paper Prepared for Expert Meeting on Environmental Requirements and International Trade October 2-4, 2002, Geneva, p. 17. Available at <http://r0.unctad.org/trade_env/test1/meetings/envreq/paper%20WTO-geneva-tex.pdf> [Accessed 15 November 2015]

O TEXTILES (2011a): *Estimating the carbon footprint of a fabric.* Wordpress [online]. Available at <https://oecotextiles.wordpress.com/2011/01/19/estimating-the-carbon-footprint-of-a-fabric/> [Accessed 25 September 2015]

O TEXTILES (2011b): *Formaldehyde in your fabrics.* Wordpress [online]. Available at <https://oecotextiles.wordpress.com/2011/01/04/formaldehyde-in-your-fabrics/#_ftn2> [Accessed 22 November 2015]

PUMPKIN INTERACTIVE (2011): *Textiles: Environmental Impacts (Preview).* YouTube [online]. *Video file*. Available at <https://www.youtube.com/watch?v=NXTIfcfzSnE> [Accessed 22 September 2015]

RUPP, J. (2008): *Ecology And Economy In Textile Finishing. Water and energy usage reductions by the textile dyeing and finishing sector can help reduce global carbon dioxide emissions..* Textile World Asia [online]. Available at < http://www.textileworld.com/Issues/2008/November-December/Features/Ecology_And_Economy_In_Textile_Finishing> [Accessed 15 November 2015]

RUPP, J. (2010): *China Textile City is a textile distribution center that's so large, it's almost impossible to imagine.* Textile World Asia [online]. Available at <http://www.textileworldasia.com/Issues/2010/April-May-June/Features/China_Textile_City> [Accessed 12 November 2015]

TEONLINE (n.a.): *Dyeing Process*. TEOnline [online]. Available at <http://www.teonline.com/knowledge-centre/dyeing.html> [Accessed 24 September 2015]

UPHAM, B. C. (2009): *AirDye: Dyeing Fabric Without Water*. Triple Pundit [online]. Available at < http://www.triplepundit.com/2009/07/airdye-dyeing-fabric-without-water/> [Accessed 23 September 2015]

VIETRADE (2014): *Vietnam's textile and garment exports posted a big soar.* Vietnam Industry News [online]. Wednesday, 02 April 2014 14:09. Available at <http://www.vietrade.gov.vn/en/index.php?option=com_con-

tent&view=article&id=2176:q12014-vietnams-textile-and-garment-exports-posted-a-big-soar&catid=270:vietnam-industry-news&Itemid=363> [Accessed 11 November 2015]

WTO (2013a): *International Trade Statistics 2013: Table II.65 Textile exports of selected economies, 1990–2012.* WTO [online]. *(xls)*. Available at <https://www.wto.org/english/res_e/statis_e/its2013_e/its13_merch_trade_product_e.htm> [Accessed 10 November 2015]

WTO (2013b): *International Trade Statistics 2013: Table II.70 Textile exports of selected economies, 1990–2012.* WTO [online]. *(xls)*. Available at <https://www.wto.org/english/res_e/statis_e/its2013_e/its13_merch_trade_product_e.htm> [Accessed 10 November 2015]