NO WATER NO LIFE, NO WATER NO PEACE

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1 Abstract

“No water, no life – no water, no peace”: This document is a collection of several scientific reports and studies carried out upon a project work of a German-Indian Exchange program. The present work reports on the physical-chemical properties of water, the impact of climate change on the development of the ecosystems in Cuxhaven and Kolkata, the structure and specialities of aquatic ecosystems in Cuxhaven and Kolkata, the effort of water abstraction and purification in both regions as well as differences in their respective water qualities.

There are three main properties of “water”. The arrangement of the molecules is variable. In the liquid state of water, the molecules have got space around themselves to be able to move. This leads to the movability of water into other shapes. In the other aggregate phases water molecules have different arrangements. Water has got special intermolecular forces like high surface tension. The third one is the aspect of heat storage capacity.

The natural conditions of the availability of water in different regions are affected by the man-made climate change. In Cuxhaven, the sea level rise will become visible as salinization of the ground water, so, there will be a drinking water shortage. In Kolkata, the main development due to climate change is the higher possibility of storm surges and resulting floods.

Focusing on the aquatic ecosystems, the East Kolkata Wetlands were described in detail. The report about the effort of water abstraction and purification in both regions considered efforts necessary to remediate wastewater in the East Kolkata Wetlands as well as to deduce the differences in effort and circumstances of water abstraction and purification in Cuxhaven and Kolkata.

Concerning differences in their respective water quality, samples of different water bodies were compared.

2 Einleitung / German Introduction

„Alles ist aus dem Wasser entsprungen! Alles wird durch das Wasser erhalten! Ozean, schenk uns dein ewiges Walten!“ (Johann Wolfgang von Goethe, 1749-1832, „Faust II“)

Schon Goethe erkannte, dass Wasser ein wichtiger Bestandteil des Lebens auf der Erde ist, denn zwei Drittel der Erdoberfläche wird von Wasser bedeckt. Davon sind aber 97 Prozent Salzwasser. Von den zweieinhalb Prozent Süßwasser auf der Erde sind außerdem etwa zwei Drittel in den Eiskappen der Pole und in Gletschern gebunden. Die unterirdischen Grundwasservorkommen machen ungefähr ein weiteres Drittel der Süßwasservorräte aus, und nur 0,3 Prozent des Süßwassers lassen sich in Oberflächengewässern wie Flüssen, Bächen und Seen wiederfinden (Abb. 2.1; BMU, 20098).

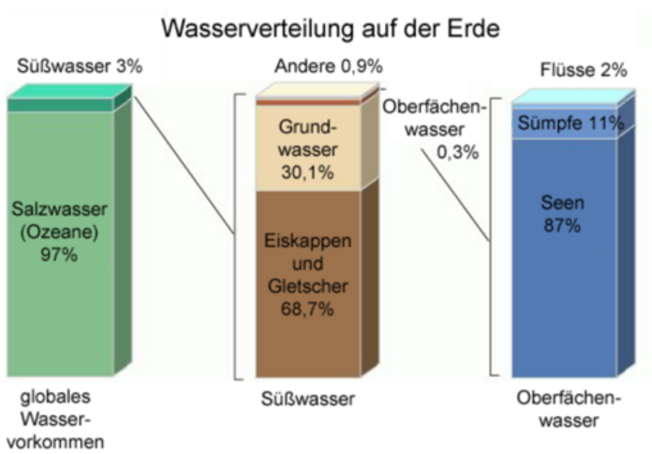


Abb. 2.1; Diese Abbildung zeigt die Wasserverteilung auf der Erde und wie begrenzt das nutzbare Wasser ist (Wikipedia.org, Referenz zu U.S. Geological Survey)

Jedoch verbrauchen Menschen immer größere Mengen Wasser. In den letzten 100 Jahren hat sich der Wasserverbrauch der Menschen verzehnfacht, obwohl sich die Bevölkerung „nur“ vervierfacht hat (BMU, 2008). Der Großteil des Wasserverbrauchs der Menschen findet unbewusst statt, dazu gehört auch der Verbrauch von virtuellem Wasser. Virtuelles Wasser beschreibt die Menge des Süßwassers, die bei der Herstellung von Produkten verwendet wird, wie z.B. bei der Herstellung von Schokolade oder Papier. Bei der Herstellung von einem Riegel Schokolade werden 500 Liter Wasser verbraucht, und für ein Blatt Papier werden 10 Liter verwendet (Klimahaus Workshop „Virtuelles Wasser“, 2018). Hinzu kommt die Nutzung von Waschmaschine, Dusche, Toilette usw., die den Verbrauch eines deutschen Bürgers umgerechnet auf 3900 Liter pro Tag bringen (Welt, 2018, Abb.2.2: BMU 2008). Die Menge an Wasser, die ein Mensch am Tag verbraucht, z.B. zum Tomatengießen, setzt sich aus verschiedenem „Wasser“ zusammen. Diese bilden den Wasserfußabdruck, der aus „Grünem“, „Blauem“ und „Grauem Wasser“ besteht. Dabei steht das „Grüne Wasser“ für natürliches Wasser,

wie Regenwasser, das die Tomate bewässert, das „Blaue Wasser“ steht für die künstliche Bewässerung, wie von einer Gießkanne, einem Gartenschlauch oder einer Bewässerungsanlage. Das „Graue Wasser“ ist die Wassermenge, die während des Herstellungsprozesses eines Produktes direkt verschmutzt wird und daher nicht mehr nutzbar ist, oder, die im Prinzip dazu nötig wäre, um verschmutztes Wasser so weit zu verdünnen, dass allgemein gültige Standardwerte für die Wasserqualität wieder eingehalten würden (Klimahaus Workshop „Virtuelles Wasser“, 2018). Durch den ausgeprägten Handel auf der Welt wird auch viel mit virtuellem Wasser gehandelt. Dieser Vorgang kann zu Problemen führen, denn die Produkte, die viel Wasser zur Produktion benötigen, können in wasserarmen Ländern zu Wassermangel führen. Länder ohne generelle Wasserversorgungsprobleme wie Deutschland hätten mit der Produktion solcher Waren nicht so viele Probleme, trotzdem importiert Deutschland viele Waren, die viel virtuelles Wasser enthalten und bringen somit andere Länder dazu, deren Wasser zur Produktion zu nutzen.

Darüber hinaus ist der Zugang zu sauberem Wasser auf der Erde ungleich verteilt. Somit haben manche Menschen in Entwicklungsländern gerade mal so viel Wasser pro Tag zur Verfügung, wie wir für eine einzige Toilettenspülung verbrauchen.

Abb. 2.2 zeigt den unterschiedlichen Verbrauch von Wasser in verschiedenen Ländern (BMU, 2008)

In vielen trockenen und halbtrockenen Gebieten wie Nordafrika oder dem Nahen Osten regnet es zu wenig, sodass die Wasservorräte in den Flüssen und im Grundwasser nicht aufgefüllt werden können. Dazu kommt der Bevölkerungsanstieg, der zusammen mit der ansteigenden wirtschaftlichen Entwicklung, sowie der Umweltverschmutzung und der Wasserverbrauch für Industrie und Landwirtschaft (virtueller Wasserverbrauch, s.o.), insgesamt die Wasserknappheit in einigen Regionen weiter verstärkt. In den Regionen Afrika, Peru, Indien usw. herrscht zurzeit schon starker Wassermangel (Abb. 2.3; BMU, 2008).

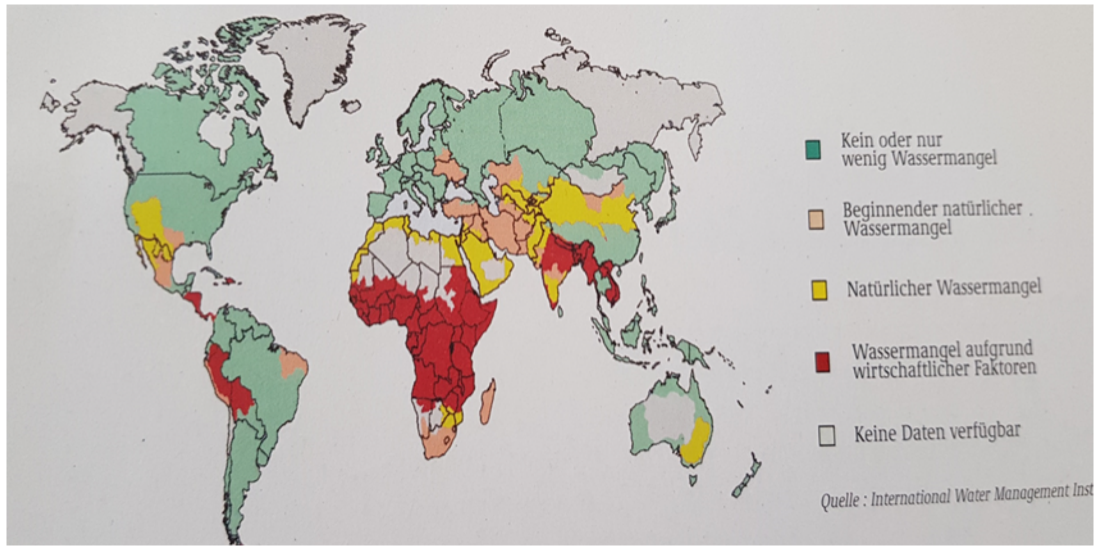


Abb. 2.3 Regionen der Erde, die mit Wassermangel zu kämpfen haben (BMU, 2008)

Durch die steigende Weltbevölkerung wachsen auch die Städte und somit auch die Anzahl der Stadtbewohner, so sollen bis 2030 75 % der Menschheit Stadtbewohner sein. Dieser rasante Wandel wird besonders in den Entwicklungsländern deutlich, denn in den letzten 40 Jahren wurden aus kleinen unbedeutenden Städten so genannte „Megacities“ mit über 10 Millionen Einwohnern in den Ballungsräumen.

Jedoch entstehen so auch viele Armen- und Elendsviertel, die sogenannten *Slums*, die ohne Planung wachsen und somit viele Probleme bei der Versorgung der Bevölkerung mit sich bringen. So haben viele Menschen in der Stadt keinen Zugang zu sauberem Trinkwasser oder zu einer funktionierenden Abwasserentsorgung (Abb. 2.4 – 2.5, BMU, 2008). Das Abwasser fließt oft ungeklärt in Bäche, Flüsse oder Kanäle und Wasser muss von weit hergeholt werden und dann teuer verkauft werden. Dann besteht die Gefahr, dass sich durch die schlechten hygienischen Verhältnisse Keime im Wasser vermehren und zu gefährlichen Durchfallkrankheiten führen z.B. Ruhr, Typhus und Cholera (BMU, 2008). Um Krankheiten o.ä. zu vermeiden wird das Wasser in Klärwerken gesäubert und schädliche Chemikalien wie Nitrit und Nitrat, welche zum Beispiel durch das Düngen in der Landwirtschaft in

das Grundwasser gelangen, werden herausgefiltert. Auch Sanitäranlagen mit gemäßer Fäkalienentsorgung sind bei rund 4 Milliarden Menschen nicht vorhanden oder nicht aktiv aufgrund Wassermangels. Dennoch haben laut der von UNICEF und WHO am 18.06.2019 veröffentlichen Daten jetzt schon mehr als 2 Milliarden Menschen keinen Zugang zu sauberem Trinkwasser.

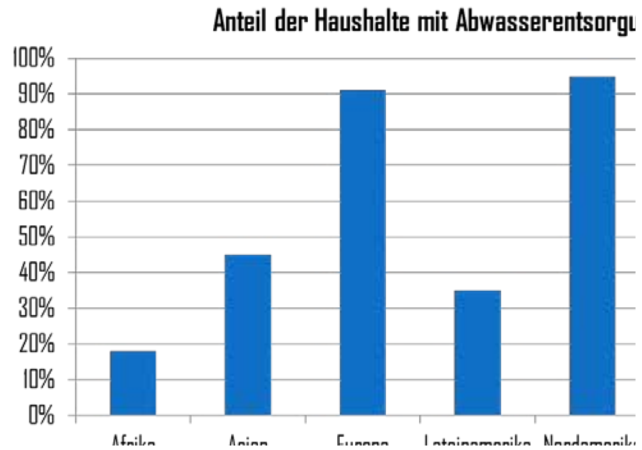


Abb. 2.4: Die Abbildung stellt den Anteil der Haushalte mit Abwasserentsorgung auf den unterschiedlichen Kontinenten dar (BMU, 2008).

Doch Wasser ist eine Lebensgrundlage für jeden. Wir können ohne Wasser nicht leben. Es ist die wichtigste Ressource und ist nicht ersetzbar.

Ob als Trinkwasser, zur Zubereitung von Speisen, im Haushalt oder für die Hygiene, Trinkwasser, oder auch Süßwasser ist sehr vielseitig einsetzbar und wichtig.

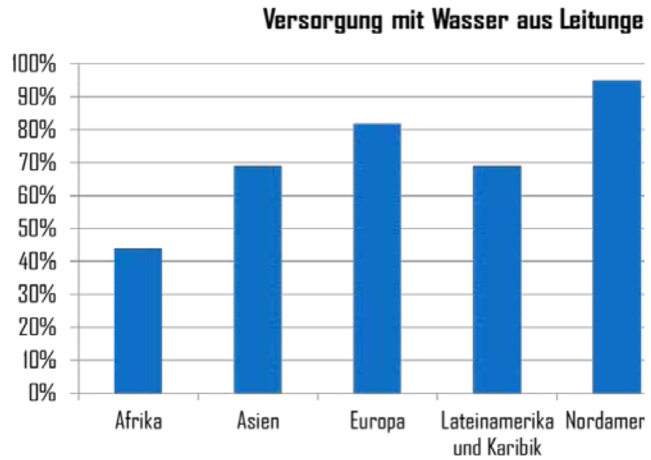


Abb. 2.5: Die Abbildung stellt die Wasserversorgung der Haushalte mit Wasser aus Leitungen auf den unterschiedlichen Kontinenten dar (BMU, 2008).

Wasser hat weitaus mehr Eigenschaften, die das Leben auf der Erde erst möglich machen. Dazu gehören vor allem die chemischen Eigenschaften wie Oberflächenspannung, die spezifische Wärmekapazität, die Löslichkeit von Gasen mit Wasser und die Veränderung der Dichte bei verschiedenen Temperaturen. Diese Eigenschaften machen Wasser zu einem einzigartigen Stoff, welche wir während des vorgestellten Schüler/innen-Austauschprojekts mit spezifischen Experimenten untersucht haben. Dabei sind wir zu interessanten Ergebnissen gekommen, die in den nachfolgenden Berichten genauer dargestellt werden.

Fragestellungen der vorliegenden Arbeit

Wasser bildet also die Grundlage des Lebens auf der Erde, aber trotz der insgesamt großen Verfügbarkeit des H_2O- Moleküls stellt die Versorgung mit sauberem Wasser ein wachsendes Problem auf der Erde dar. Daher wurde auf dem Kongress „World Water Week“ 2017 in Stockholm die Aussage geprägt „no water, no life – no water, no peace“ (Zitat). Das bedeutet, ohne eine Lösung dieses Problems wird es auf der Erde keinen dauerhaften Frieden geben. Um uns dieser Problematik zu nähern, sollten mit dem vorliegenden Projekt folgende Fragen beantwortet werden:

– Welche physikalisch-chemischen Eigenschaften machen das Wasser zur Grundlage des Lebens auf der Erde?
– Inwiefern trägt der Klimawandel zur Veränderung der Wasserverteilung auf der Erde bei?
– Welche aktuellen Bedrohungen bestehen für die Lebensräume „Wattenmeer“ (UNESCO-WELTERBE) und Wetlands (RAMSAR Site) und wie kann man sie schützen?
– Wie unterscheiden sich die Trinkwassergewinnung und Abwasseraufbereitung in der Region Cuxhaven und der Region Kolkata?
– Wie kann man die Ressource Wasser besser schützen?
– Wie unterscheiden sich die Wasserqualitäten verschiedener Wasserkörper in der Region Cuxhaven und Kolkata?
– Gibt es eine Verbesserung der Wasserqualität in Cuxhaven und Kolkata über den Zeitraum von 2018 bis 2019?

3 Properties of water

3.1. Abstract

Water has different properties that make it unique and allow for the existence of life on earth. The properties are due to the arrangement of the molecules and the intermolecular forces responsible. Some of those special properties are cohesion, surface tension, density abnormality and the heat storage capacity.

3.2. Introduction

When we find water here on Earth — whether it be ice-covered lakes, whether it be deep-sea hydrothermal vents, whether it be arid deserts —if there's any water, we've found microbes that have found a way to make a living there (Ghose, 2015).

Because of this basic importance of water, some of the properties of water were investigated in the following.

3.2.1 Cohesion and surface tension

Water molecules are polar, that is, one end of the molecule is more electronegative than the other end. Therefore, the opposite ends of different water molecules are attracted to each other like the opposite ends of magnets. The attractive forces between water molecules are known as "hydrogen bonds”. The hydrogen bonding tendency of water causes it to be 'sticky,' in that water molecules tend to stick together (as in a puddle). This is known as cohesion. Because of this property, water has a high surface tension. This means that it takes a little extra force to break the surface of the water puddle (Wikipedia.org, Redaktion SimplyScienc, 2012).

Surface tension is the tendency of fluid surfaces to shrink into the minimum surface area possible. This tendency is responsible for the spherical shape of water droplets because, for a given volume, a sphere has minimum surface area. Surface tension allows insects (e.g. water striders), usually displaying a higher density than water, to float and slide on a water surface (Wikipedia.org).

At liquid–air interfaces, surface tension results from the greater attraction of liquid molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion). The net effect is an inward force at its surface that causes the liquid to behave as if its surface was covered with a stretched elastic membrane. Thus, the surface comes under tension due to the imbalanced forces, which is probably where the term "surface tension" originates from (Wikipedia.org). Because of the relatively high attraction of water molecules to each other through a web of hydrogen bonds between the molecules, water has a higher surface tension (72.8 millinewtons per meter at 20°C) than most other liquids.

3.2.2 Adhesion

Water is also adhesive, meaning that it tends to stick to other molecules besides water. Because of this, the effect of capillarity occurs in the vessels of trees due to which the trees can grow up to 130 m, i.e. allowing for water supply of the leaves up to a height of 130 m, therewith overcoming gravity (biology.stachexchange.com. n.y.). In particular, the water molecule it will stick to water soluble (=hydrophilic, polar) substances, such as starch or cellulose. It will not adhere to hydrophobic (lipophilic, nonpolar) substances, such as oil.

3.2.3 Water expands when it freezes (density abnormality)

The high number of hydrogen bonds that exist within liquid water cause longer distances between water molecules than the between molecules, in other liquids (the bonds take up space themselves). In liquid water, hydrogen bonds are constantly being formed, broken, and reformed, so, macroscopically, the water can flow without a specific shape. However, when water is cooled from 4.0°C to 0.0°C, the bonds can no longer be broken, because there is not enough heat energy to do so. Therefore, the water molecules form a lattice that is more expansive than water in liquid form. Because the frozen water contains the same number of molecules but is more expansive, it is less dense than liquid water in the temperature range 4.0-0.0°C. The less dense ice (solid water) will therefore float over the more dense liquid water.

A film of ice on top of a body of water acts as an insulator. As a result, the liquid water underneath the ice will be protected from the outside air and will be less likely to freeze as well. This is yet another reason that water is able to maintain a consistent temperature of 4°C allowing for survival of aquatic animals during winter (Wikipedia.org).

3.2.4 Water is a good solvent

As the water molecule is polar (actually, it represents a dipol), in nature, other polar molecules will readily dissolve in it. Generally, in polar molecules, there is a negative charge on one end of the molecule, which is attracted to the positive charge of the other end of other molecules, similar to a magnet. This attraction results in water molecules surrounding dissolved polar molecule by a net of hydrogen bonds. That is why polar molecules are also known as hydrophilic (water-“loving”) or water-soluble molecules. However, water does not dissolve nonpolar or hydrophobic (water fearing) molecules well. Hydrophobic molecules include oils and fats. In fact water is referred to as a universal solvent because it dissolves most of the materials and not all materials (Wikipedia.org).

More precisely, the following questions were addressed:

- How much gas can be dissolved in water?
- What is the anomalous expansion of water?
- How to visualize the high surface tension of water?

3.3. Material & Methods

3.3.1 Surface tension

In the first experiment a bowl of water was prepared and a paper clip and a pin were put on the water surface. Afterwards detergent was added to the bowl of water.

Fig. 3.1: A drop of water is put on the feather (photo: Keuser, 2019)

In the second experiment a coin was rubbed between the fingers and then given on the water surface. Additionally, water was dropped on a coin, the drops were counted and the shape of the water was observed. At the end detergent was added to the water on the coin.

In the last experiment on surface tension a microscopic slide and a feather from a duck were prepared and a drop of water was put on both (Fig. 3.1). Then the angle of each drop was determined three times. Afterwards this process was repeated with water mixed with detergent drops.

3.3.2 Heat conduction and heat storage capacity of water

In this experiment 100 ml of water and oil each had to be added into Erlenmeyer flasks and these were put into a water bath within beakers which then were placed on a heating plate. Subsequently, a thermometer was placed into each liquid and it was waited for the temperature to equalize. Both liquids were heated over five minutes and the temperature changes of the liquids were noted every minute (Fig. 3.2). To specify the results the experiment was repeated and the mean values were calculated.

Fig. 3.2: Experimental set up of the experiment observing the temperature changes (photo: Keuser, 2019)

3.3.3 Density changes at different water temperatures

To visualise the density changes of water at different temperatures an Erlenmeyer flask was filled with water that had a temperature of 14°C. In the Erlenmeyer flask a tube with a fixed ruler and a thermometer were positioned and this construction was put into a freezing mixture of water, ice and salt (Fig. 3.3). During cooling the water level was determined for different temperatures. This experiment was repeated twice and afterwards carried out again using alcohol (spirit).

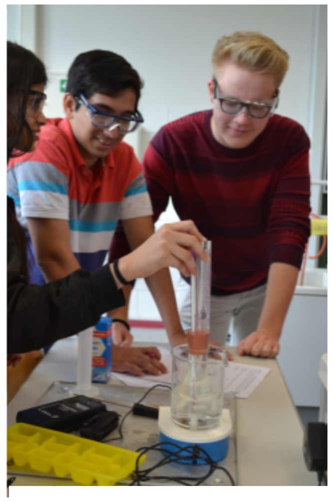


Fig. 3.3: Observation of the volume of the water (photo: Keuser, 2019)

3.3.4 Solubility of gases at different temperatures

At the beginning a gas syringe was filled with 60 ml carbon dioxide (g) and 20 ml water (l) was added. After closing the syringe it was shaken gently to achieve a constant volume that was noted. Afterwards, to determine the dependency of solubility on pressure, the pressure within the syringe was carefully increased and the syringe shaken again until volume constancy. Then the forcer was pulled out and a fresh mixture of gas and water was added. To determine the dependency of solubility on temperature the first two steps were repeated with water that was previously heated to about 50°C or cooled down to 0-4°C. Each experimental part had to be carried out three times with fresh water and fresh carbon dioxide. Also, the respective temperature of all water samples used was noted.

3.4. Results

3.4.1 Surface tension

As the paper clips and the pin were put on the water surface they were swimming on the surface. After addition of detergent to the water the paper clips and the pin were sinking to the ground.

In contrast to this, the coin didn't even swim on the surface neither with nor without detergent added to the water.

Adding water droplets on the coin a water hill was formed. 42 drops could be put on the coin before the round and mostly symmetric water hill broke down and the water flew away. But after addition of detergent the water hill became destroyed and the water flew away immediately.

As result from the angle determination of water drops on a microscopic slide and a duck feather we could notice that the angle was generally higher on the duck feather than on the microscopic slide. On the microscopic slide the angle was about 1° and on the feather about 5°.But the angle of drops of water mixed with detergent was very small and not measurable.

3.4.2 Heat conduction and heat storage capacity of water

The water took longer time than the oil to be heated up (Tab. 3.1).

Tab. 3.1: Time-dependent changes of water and oil temperatures upon heating; MV = mean value

Minute	0	1	2	3	4	5
Oil measure 1	21°C	21°C	27°C	36°C	48°C	58°C
Water measure 1	21°C	24°C	30°C	38°C	45°C	53°C
Oil measure 2	20°C	20°C	27°C	36°C	48°C	58°C
Water measure 2	20°C	25°C	28°C	38°C	45°C	53°C
MV oil	**20.5°C**	**20,5°C**	**27°C**	**36°C**	**48°C**	**58°C**
MV water	**20.5°C**	**24.5°C**	**29°C**	**38°C**	**45°C**	**53°C**

3.4.3 Density changes at different water temperatures

When the water was cooling down from 14 to 0°C the water level decreased within the range from 14 to 4°C and then the level increased again in the range from 4 to 0°C. In contrast, the level of alcohol continuously decreased upon cooling down from 14 to 0 °C.

3.4.4 Solubility of gases at different temperatures

At room temperature, which generally is around 20°C, there about 11 ml of gas (carbon dioxide) could be solved. When the water was warmer than this, like 51°C, it was about 4 ml and at cold water, like 1°C, about 23.5 ml. So, solubility of gases such as carbon dioxide increased with decreasing temperature (Tab. 3.2).

Tab. 3.2 Solubility of carbon dioxide in water at different water temperatures; MV = mean value

	Water at RT	Cold water	Warm water	RT/ pressure
Observed (1) temperature	20°C	1°C	51°C	20°C
Diluted (1) gas volume	11 ml	23.5 ml	4 ml	22 ml
Observed (2) temperature	20°C	2.5°C	67°C	20°C
Diluted (2) gas volume	14 ml	24 ml	0 ml	22 ml
Observed (3) temperature in C	21°C	3°C	55°C	20°C
Diluted (3) gas volume in ml	16 ml	21 ml	3 ml	21 ml
MV temperature	**20.3°C**	**2.16°C**	**57.3°C**	**20°C**
MV gas volume	**13.6 ml**	**22.83 ml**	**2.3 ml**	**20.3 ml**

3.5. Discussion

3.5.1 Surface tension

The phenomenon of surface tension represents a unique property for liquid substances. This property is the reason why the paper clip and the pin can swim on the water. The surface tension is strong enough to hold light objects like a pin but cannot hold heavier objects, e.g. a coin. As animals such as insects display a very low body mass they are able to walk on the water surface, e.g. of a pond (Wikipedia.com).

The property of surface tension is caused by the molecular arrangement of H_2O. The molecules are connected by intermolecular forces. There are two famous forces called van der Waals forces and hydrogen bounds which connect molecules. The hydrogen bounds are much stronger but can only be built between molecules consisting of hydrogen together with oxygen, nitrogen or fluor atoms. Between the H_2O molecules the hydrogen bounds can develop and so strong intermolecular forces emboss water. In contrast to the polar water the air is nonpolar, so the water molecules try to bend down in the opposite direction (SITA Messtechnik, 2017). Consequently, the forces effect downwards, making the surface appearing like a “skin”. This effect, thus, is called surface tension.

Adding detergent destroys the cohesion of water molecules by hydrogen bonds and, thus, destroys the surface tension. By contrast, the nano-structure of the duck feather increases the surface tension, similarly to the lotus effect. Thus, the angle of the water hill is bigger for drops on the feather than for drops on microscopic slide made of glass. With respect to the duck, this application of the surface tension is important for keeping the feathers clean (Wikipedia.org).

3.5.2 Heat conduction and heat storage capacity of water

Water has a high heat storage capacity, which means that it needs more energy to be heated up. That is why it takes longer than the oil, which has a lower heat storage capacity. Due to the fact that water molecules are connected by hydrogen bonds, which are the strongest types of intermolecular bonds, more energy is needed to break up those bonds, with is seen in the longer time (tab. 3.1) and in a higher boiling point due. By contrast, oil molecules are connected by van der Waals forces, which are not as strong as hydrogen bonds. That is why less energy is needed to overcome the attraction of the molecules to one another and, consequently, the boiling point is lower than the one of the water.

3.5.3 Density changes at different water temperatures

Water is unique because it behaves different during cooling down in comparison to all other liquids. The volume of the water decreases from the temperature 14 degrees to 4 degrees and after that the volume increases again. This change is caused by the arrangement of the water molecules. At a lower temperature the water molecules start to build a hexagon of molecules. This structure leads to an increasing volume because it needs more space than the structure of the molecule connection when it is liquid. This also leads to a decreasing density because in the middle of the hexagon are no molecules. In comparison to water alcohol has a continuous decreasing volume. This special property allows for animals to survive winter times on the bottom of a lake without becoming frozen (Wikipedia.org).

3.5.4 Solubility of gases at different temperatures

Water has the property to solve gases at different temperatures. When cold water is used, more gases can be solved. This belongs to the distance between the water molecules. In cold water, the movability of molecules is reduced and the water molecules become closer to each other than in hot water. So there is more space left which can be used by the gas molecules. When the water would be hot the molecules would engage more space and less gas, i.e. fewer molecules, can be solved.

3.6. Conclusion

The force of attraction between the water molecule is high (cohesion), which leads to a high surface tension in water because the forces effect inwards and as a result water occupies the least surface area, taking a spherical shape. Water also has a strong force of adhesion and is hydrophilic in nature; it is called a universal solvent because it dissolves most of the materials. Additionally, water also exhibits the phenomenon of anomalous expansion whereby on being cooled beyond 40°C it expands rather than contracting. This reduces its density and increases its volume. These properties are very important for certain organisms and, together, allow for life on earth. In the present article, these properties have been demonstrated in the various experiments conducted.

4 Water supply: The Ganges and the Himalayas – Overall importance for India and possible improvements

4.1 The Himalayas

The Himalayas are a high mountain system in Asia. The Himalayas are the highest range on earth and lie between the Indian subcontinent in the South and the Tibetan highlands in the North.
The Himalayas include over fifty mountains exceeding 7,200 m in elevation among the Mount Everest, the highest mountain on earth with 8848 m in elevation (fig. 4.1) (Wikipedia.org).

Fig. 4.1: Map of the Ganges (yellow), Brahmaputra (purple), and Megha (green) drainage basins (Wikipedia.org)

4.2 Himalayas' general importance

Economically, India could not exist without the Himalayas, the country lives from their water. Because of the special stone types of biotriched gneiss, coarse-grained shale and granite blocks the water includes important substances which can have positive as well as negative effects for nature and organisms. The most important water source for India is the river Ganges, which rises from the Himalayas.

4.3 Himalayas effect on drinking water

The Himalayas range contains stones which are partly made of arsenic. Arsenic is naturally present in these stones. Arsenic is affected by several chemical processes under the influence of weathering, oxygen and water. Because of depletion of the water the groundwater table decreased and effects that the air can expand to the clay stratum of the Himalaya. Under the influence of the air and its oxygen the arsenic is changed into soluble compounds and set free into the water. The arsenic contaminated water flows into all the rivers rising in the Himalayas Mountains. Also, the Ganges water is affected, and whose water is used as drinking water by poor people. After a long time of using this contaminated water people can get heavy diseases, which can be deadly.

4.4 Importance of the river Ganges

The Ganges is one of the most important rivers in India. It has a length of 2.525 kilometres and a width of 322 to 644 kilometres. Rising in the Himalaya in Nepal the Ganges flows through India and Bangladesh emptying into the Bay of Bengal (fig. 4.1). The Ganges has a great importance for Hindus in many ways. Its importance reaches from religious and cultural over to economic and, finally, ecologic and environmental significance (Fig. 4.2). In the following we are focusing on these three topics (Wikipedia.org). In addition to that significance, especially homeless people use the river for bathing and washing their cloths and cooking equipment. As they more or less spend their lives next to the river this leads to a high amount of pollution (own observations).

Fig. 4.2: People in the surroundings of Kolkata bathing in the Ganges (photo: Steinmetz, 2019)

NO WATER, NO LIFE – NO WATER, NO PEACE

4.4.1 Religious and cultural importance of the Ganges

The Ganges has an immense significance concerning the topics of religion and culture (Wikipedia.org).

4.4.1.1 Representation of sacredness

The river and its water are sacred to Hindus. For example, they use the water for rituals. Furthermore, the process of bathing in the Ganges, besides simple washing (fig. 4.2) has a huge meaning for Hindus. By bathing or lifting water in your hands and letting it fall back they pay homage to their ancestors and gods (Wikipedia.org).

Fig. 4.3: Bathing procedure to get the salvation (Wikipedia.org)

4.4.1.2 Salvation of the dead

Ganga, the goddess of rivers, descended on the earth to wash away all sins of the mankind. According to beliefs, Ganga used the Ganges to rise up to heaven to sanctify gods with her holy water of the Ganges (Welt der Wunder Magazin, 2019.). Due to the fact that she flew to heaven with the Ganges, it is a vehicle of ascent for Hindus. That is why people want to be close to the holy river when having their last breath. There are two different ways of getting salvation. To get salvation the corpse is either bathed, wrapped in cloths, covered with wood and then thrown into the Ganges (fig. 4.3) or, if the corpse is burnt, salvation is got by dispersing the ashes into the river (Wikipedia.org).

4.4.1.3 The purifying Ganges

In Hindu beliefs rivers are pure and cleansing by cause of their moving water. This is because they believe that the movements absorb impurities and take them away. The Ganges is especially purifying for them, due to the fact that its water is very fast moving. It removes not only physical dirt but also symbolic one which means that it wipes away sins of a lifetime (Wikipedia.org, 2019b).

4.4.2 Economic importance of the Ganges

The river Ganges has an extraordinarily importance in Kolkata's economy mainly in two topics, one of them being agriculture (fig. 4.4) where the population gains money by selling vegetables or similar products that grow next to the river. The other topic is the tourism which by which Kolkata gains money by attracting people which need to stay somewhere near the Ganges (Wikipedia.org).

Fig. 4.4: Agriculture next to the river Ganges (gangaaction.org, n.d.)

4.4.2.1 Agriculture

The Ganges is important for Kolkata's agriculture. The area next to the river consists of fertile soil which is a property beneficial to farming (fig. 4.4). That is why farmers can grow rice, sugarcane, lentils, oil seeds, potatoes and wheat over there. Other good features for agriculture are swamps and lakes which you can find in the area around the river. These rich growing regions are also perfect for chilies, mustard, sesame and jute. Furthermore, the lakes also provide great fishing opportunities (Wikipedia.org).

Fig. 4.5: river rafting (pixabay.com, 2008)

4.4.2.2 Tourism

The river Ganges has a huge significance for Kolkata's tourism. It attracts a lot of people. On the one hand pilgrims who want to bathe in the holy waters, on the other hand tourists who want to have fun such as river rafting (fig. 4.5) or walks on walkways along the banks (Wikipedia.org). Together, this provides employment for a number of people inhabiting this region.

4.4.3 Ecologic and environmental significance

With respect to ecology and environment the Ganges shows a huge importance not only for the city of Kolkata. The Ganges and its surrounding represent a habitat for many species. However, due to the human development the natural vegetation of the basins of the Ganges got replaced leading to destruction of habitats for many animals such as birds, wild animals, fish, crocodilians, turtles and even more (Wikipedia.org).

Furthermore, the fast melting of the Tibetan glaciers caused by the climate change leads to expansion of the Ganges. This forms the base for floods and mudflows. When the glaciers, which are lifelines for a lot of Asian rivers, melt down completely the water supply for many cities would be in danger, among them the megacity of Kolkata whose biggest water supplier is the river Ganges (Wikipedia.org; p.c. R.M. Chatterjee, 2019).

In the following we will discuss how and where the "holy" water of the Ganges gets purified and filtered to become potable water to supply households and pumping stations in Kolkata. The presented information is based on explanations given by R.M. Chatterjee, the former Director general operations (water supply), K M D A.

4.5 Water Treatment Plant

The presented water plant is situated in Serampore in the North of Kolkata because at this certain location the water of the Hooghly (the side arm of the river Ganges passing by Kolkata) is "sweet", i.e. freshwater, while in centre of Kolkata, the water is brackish. This water treatment plant produces 90 million litres of water per day and supplies 7 towns.

The turbidity of the river water due to sludge, sand, wastes varies from 80 Nephelometric turbidity Units (NTU) in summer to 800 NTU in rainy seasons. However, for pure water the turbidity should be less than 1 NTU and, additionally, there should be no microbes and no harmful chemicals in the water.

4.5.1 Source of the potable water

Basically, the water source for the water treatment plant is a mixture of the ground water and surface water. The ratio is 1:8 (Ground water: 11.5%; surface water: 88.5%). Because of the necessity to use surface water, which is turbid, the mixture water needs extensive treatment. Whereas the ground water is abstracted from underground aquifers fed from rivers, rainwater and water bodies that are naturally less turbid, the surface water is taken from rivers, lakes and ponds fed from springs, glaciers and rain.

4.5.2 Purification process

There are various steps in the process of cleaning up the water to become potable:

The first procedure is the so-called abstraction, where the water is drawn from the river Ganges using four centrifugal pumps and is led to the actual plant.

The second process is the pre-chlorination, wherein the water arriving in the plant is pumped to the collecting well from where the water is gushed through the partial tube. Here, chemicals are added to the water to remove bacteria. Alum is added due to which the positively and negatively charged ions combine and become insoluble and sediment to the bottom, thereby separating the impurities. Also, chlorine is added in a high dose and that is why this process is called pre-chlorination. Chlorine is the only substance which, when added to water, kills bacteria but does not harm the human body when the water is consumed. During this process the water has a very turbulent flow so that the chemicals and water are mixed efficiently. Also, this step the process is supported by a flush mixer machine. Ultimately, turbidity is reduced to greater than 200 NTU.

The third step is called foam formulation taking place in circular tanks. In the central part of those circular tanks there is a turbulent water flow and here, the slag, which floats on top, can get separated. The water has a brownish colour at that time.

The fourth procedure is called clariflocculation, where the water flow is steady which facilitates colloidal sedimentation. As the turbidity comes down to 10 NTU, the water appears more greenish and less brownish.

The fifth step is the filtration, where the water is passed through a filtration bed composed of different materials like sand, gravel-sand and grains. Here, the turbidity

is reduced to less than 1 NTU which is the desired amount. After this process the water is pure. Whenever the filtration rate is reduced, it implies that the bed is choked and needs to be cleaned.

The final step, thus, is the storage, where the water is kept in tanks after checking its quality in the laboratories for harmful chemicals and bacteria. In the case of determination of sulphates, nitrates, etc. as well as turbidity, various measuring devices are used. For the control of bacteria the colonies of bacteria like *Escherichia coli* (*E. coli*) and other faecal coliform bacteria are counted after growing on agar plates. When faecal coliform bacteria are detected the chlorination has to be increased to destroy them.

4.5.3 Storage tanks for the purified water

Chlorination is crucial because of the high content of microbes in the used water sources, such as the river Ganges. The storage of the chlorinated water needs a permanent intake of oxygen, otherwise chlorine might decompose; this process has been reproduced in a demonstrative experiment (see chapter 8). Additionally, anaerobic bacteria might also start to form (own considerations). This oxygenation is achieved by the usage of open tanks instead of a closed system.

4.6 Conclusion – Thoughts of possible improvement

In our opinion, the way Serampore is purifying the water is the most efficient way concerning their environmental and economical circumstances allowing for the supply of 7 town by purest water. Closed tanks, e.g., could help to avoid contamination of the purified water but would cause permanent high costs for pumps, needed to pump the oxygen in the tanks, as they would need electrical power to work. However, India is a developing country, so the economical conditions are not as good as e.g. in Germany. Germany, e.g. the city of Cuxhaven, is using ground water as abstraction source, which is already pure and does not need any chlorination. Thus, the tanks can be closed for storing the filtered water before transport to the households.

We think that the main problem with the storage in India is, that animals such as birds are able to enter the facility, so the water can get contaminated again, because of their faces. In conclusion, one can argue, that closed tanks are the healthiest and most efficient opportunity, even though it's very expensive in comparison to open ones. This means that until India hasn't acquired a lot of wealth, the only way to keep the water clean is by installing an animal proof tank.

Finally, the holiness of the Ganges has to be stressed in a different manner. Its continuous contamination is bad for the population but worshipping the river as described above won't stop it. The people should be educated about their hygienic misbehaviour of bathing in the river and putting their rubbish into it being harmful to their "goddess" of themselves. Also, the government should provide more people with clean water (or providing housing for the homeless) so that they don't have to choose the dirty Ganges as an alternative, making it dirtier in the process. Of course, this depends on economic possibilities of the government and an enormous challenge. Besides that, the arsenic contamination by the Himalayas must be investigated and lowered.

5 Aquatic Ecosystems

5.1 The East Kolkata Wetlands

Fig. 5.1 waste and nature - The East Kolkata Wetland ecosystem (photo: Breuer, 2019)

5.1.1 Abstract

An ecosystem basically consists of a biological community of interacting organisms and their physical environment. It is a complex network or interconnected system of all the plants and animals that live together in a particular area including all the complex relations which exist between those and their environment.

So going on with it, an aquatic ecosystem is an ecosystem in a body of water, thus, the physical environment is determined by the chemical and physical properties of water. The community is made up of all the system's plants and animals that live either in or on that water body. The specific setting and type of water, such as a freshwater lake or saltwater marsh, determines which species of animals and plants can exist there.

An aquaculture is a special kind of farming of aquatic animals or plants, including breeding, raising and harvesting in all types of water environments under controlled conditions. It is used to produce food and commercial products, restore and create healthier habitats and, also, rebuild threatened or endangered species populations. There are two basic types of aquaculture, either marine or freshwater.

The East Kolkata Wetlands (EKW) are located on the eastern fringes of Kolkata city bordering the Salt Lake township on the one hand and the new township at Rajarhat on the other. Forming one of the largest assemblages of sewage fed fish ponds the wetlands spread over an area of 12,500 hectares. The East Kolkata Wetlands nurtures the world's largest wastewater fed aqua culture system. Sewage of the city of Kolkata that is sent to the wetlands is subjected to solar purification followed by natural oxidation by which the water becomes conducive for algal and plankton growth which are the primary feed of the aquacultured fishes. The goods and services provided by the EKW include, in addition to fisheries, they are used as a very cheap, efficient and eco-friendly system of solid waste and sewer treatment system for the city of Kolkata, but also represent a habitat e.g. for waterfowl and home for many flora and fauna. Thus, the East Kolkata Wetlands are of mayor importance for Kolkata and its surroundings.

5.1.2 Introduction

Our planet is a habitat for a huge diversity of life, which includes animals, plants, bacteria, etc.

All these appearances of life are balanced among themselves. To keep this balance there are producers (mostly plants), consumers (mostly animals) and decomposers (e.g. bacteria), which feed from each other in a food chain or a food web (Williams, 2011). As human beings we are a part of the ecosystem and we have to keep this cycle running for our own survival, i.e. the survival of mankind.

An ecosystem is a community of organisms that live and interact with one another (and represent the biotic factors) within a particular environment (the abiotic factors) (Williams, 2011). In an aquatic ecosystem, that environment is water, and all the system's plants and animals live in or on that water. The specific setting and type of water, such as freshwater / saltwater / brackish water determines the kind and type of animals which live there. Because of the fact that most of the earth's surface is covered with water, which is habitat for an even bigger diversity of life then onshore, we can say that „aquatic“ ecosystems are a main issue for keeping the balance of life. As example for an aquatic ecosystem we are going to explain the importance and diversity of the East Kolkata Wetlands.

The East Kolkata Wetlands are a complex mixture of human made and natural wetlands. They are located in the East of Kolkata and are home to 20 thousand families, whereas the city of Kolkata itself is home to more than 10 million people.

In the following we are mainly going to discuss some main questions we think about whenever we hear about the East Kolkata Wetlands or Wetlands in general. The following questions came into our mind the first time we heard about the East Kolkata Wetlands being an aquatic ecosystem that is used for wastewater treatment of the whole sewage that is obtained from the inhabitants of the megacity of Kolkata:

- What are the East Kolkata Wetlands (EKW)?
- Which species are found in the Wetlands?
- Which waste elements appear in the water?
- What exactly happens to the city sewage in the EKWs?
- Are the fishes from East Kolkata wetlands infected from pathogens in the water?
- Are the fish intoxicated enough to be harmful for themselves or their consumers (humans)?

5.1.3 Discussion:

5.1.3.1 The structure of the East Kolkata Wetlands

These wetlands are like a natural "kidney" to the city's domestic sewage. It follows a naturally occurring cycle and is, thus, self-sustaining. The growth of algae is supported because of the readily available sunlight. In turn, the algae sustain the growth of bacteria which break down and help decompose solid waste present in the polluted water and simultaneously, the thriving algae also act as food required by the fish to survive and thrive. Thus, while water is being purified, there is also a massive production of fish which are eventually sold in local markets. This cycle is so affective and reliable that even after multiple instances of human intervention, it has not been disrupted (Ghosh, 1999).

All life forms, flora and fauna, here are interdependent on one another for sustenance.

The East Kolkata Wetlands are an artificial ecosystem based on biological and ecological processes made for the management of wastewater and sewage produced by the city (Ghosh and Sen, 1987).

Around the turn of the century, these low-lying areas were flourishing brackish water fish farms. The wetlands were then fed by the tides of the Bay of Bengal. However, the natural process of delta building aggravated by human intervention, caused the tidal flow to dry up, and thousands of fishermen lost their source of livelihood. But, then an amazing thing happened. During the 1930's, it was discovered that the domestic wastewater from Kolkata could form an alternative source of water to feed these fisheries. But the questions that popped up in every mind were "wouldn't the water be too polluted with organic waste? How could this polluted water be reused? Wouldn't the fish die in such water?"

But, the interesting fact was that the fish DID NOT die, when reared in this water, instead they thrived and brought the fisheries back to the market. Therefore, somehow the water must have been filtered or purified naturally making it possible for the fish to survive and thrive. How and why this happened didn't concern anyone until it was discovered by Dr. Dhrubajyoti Ghosh in the 1980's:

Basically, the system works as follows: The retention of water before the initial stocking of fish nourished by bacterial growth which for their own nourishment started acting upon the organic waste present in the water, breaking it down. The growth of these bacteria was supported by the Algae which thrived in these ponds because of the ample amount of sunshine present. These algae also acted as a food source for the fish and an extremely reliable one. So, a "Double Boon" was taking place as stated by Dr. Ghosh. The organic sewage was being treated naturally by the ecosystem, thus, acting as a kidney to the city's wastewater (Ghosh and Sen, 1987; Ghosh, 1999).

5.1.3.2 Waste present in the water treated

Now coming to our second question what are the waste elements that appear in the water? In big cities - in our specific case Kolkata - the water is used in many different ways. One of the most important use of water is dish washing (dish detergent, food residues, thus, biodegradable substances). Another important use is in the bathroom, where shampoo and soap is added as well as the use for flushing the toilet, where

faeces and toilet paper come into the water. Additionally, there is a big number of people living on the sidewalks in India which means that they wash themselves on the sidewalks as well (own observations). Of course, faecal contaminations always bare the risk to give rise to the development of common coliform bacteria but also to pathogenic bacteria. Unfortunately, the water bodies feeding the wetlands are also used for waste disposal in these areas and by waste disposal, mainly the respective plastic waste which obviously is not biodegradable (own observations). In some cases these local rivers are also used for disposal of hazardous waste or / and chemical waste, by private persons but also by local companies that are responsible for these special cases of hazardous water and chemically polluted water (Mukherjee, 2011).

Because of all these information that we have collected we can surely say that the urban wastewater contains "normal" or to be precise biodegradable pollution which is not really posing any danger but also other different pollutants on micro level such as bacteria and pathogens, from which a few can be hazardous. The urban wastewater of Kolkata is directly conducted to the East Kolkata Wetlands by sewer systems of the city, where the main solid garbage is filtered out of the water before the purification processes start.

5.1.3.3 Water treatment in the East Kolkata Wetlands

Fig. 5.2: Two of the multifunctional fishponds spread all around the EKW (photo: Breuer, 2019)

After receiving all of the city`s sewage the East Kolkata Wetlands start treating it organically. Urban wastewater supplied by the municipal corporation is routed through a series of small inlets, each managed by a fishery cooperative. The cooperatives control the inflow of the wastewater. They let it settle so that only the clearer top layers of water flow into the shallow wetland. A parabolic fish gate separates the wetland water from the wastewater. This special structure prevents fish from swimming into the oxygen-less urban wastewater, where they would die. In the meantime, “nature does its work”. In the inlets, organic waste settles down and is partly decomposed in the warm shallow water. In a series of biological steps, the organic waste in the wetland is converted into fish feed. These steps involve several ecological processes carried out by soil bacteria, macro-algae, photosynthetic bacteria and plants themselves. Together, they convert nitrate, and absorb phosphate as well as heavy metals. Upon these processes the sediments in the wastewater settle down further. As the water becomes less turbid, sunlight accelerates some of these processes (Ghosh, 1999). Notably, the activity especially of the algae, is extremely high, resulting in a higher carbon dioxide uptake than output, thus, counteracting the climate change (pers. comm. D. Ghosh, 2016 to K. Steinmetz).

5.1.3.4 Possible contaminations of the fish in the East Kolkata Wetlands

According to the above discussion we have to expect that Kolkata wastewater contains various pollutants. Of course, some of these pollutants are managed by the filtration processes or biological proceedings of East Kolkata Wetlands. After all filtration processes the filtered water is conducted to the fishponds, where it is used to provide an environment for the different species of fish. As we know at this point the water isn’t freed from pollutants yet. Fish get their oxygen from the water by their gills. Pollutants have been found in the fish of EKW aquacultures (Mukherjee, 2011). There are two ways how they can have ingested the pollutants: Either the pollutants are part of the diffusion that is part of the common breathing process where oxygen and carbon dioxide are substituted through the membranes of the gills - or the pollutants come into the fish by drinking of water upon feeding, so the pollutants enter the stomach of the fish and from there through the digestive system into the blood and other organs.

5.1.3.5 Are the toxic contents from the fish dangerous for their consumers?

Only residents and parts of the population of Kolkata feed from the fish of EKW. No information about their reaction to eating these fish is available. Thus, we cannot say if there are any diseases caused by contaminated fish. Specific studies on that topic would be necessary that, however, would be not only laborious but also cost-intensive. On the other hand, there is also a possibility of immunity development of

the residents to those possible diseases. In this case even contaminated fish would not make any harm to them.

5.1.3.6 Vertebrates found in the wetlands:

5.1.3.6.1 Fish

The fish species in wetlands largely depend on plankton in their younger stage. With the age and growth in size, these tend to feed on larger prey and organic matter from the sewage water. Previously the fish fauna in the East Kolkata Wetland system was composed of both brackish water and freshwater forms of fish. But after the large scale intervention by the owners through sewage fed cultivation of only few numbers of freshwater fish species established. Thus, diversity and populations have changed. And nowadays only freshwater fish species are recorded from these wetlands, e.g. tilapia and carp. The wetland owners commonly culture the survey results showed that 37 fish species are recorded of which 23 species are recorded as wild fish species (Ghosh, 1999).

5.1.3.6.2 Mammals

Wetland areas also offer suitable habitats to mammals as there is a diversity of different ecological niches, on one hand in the water bodies for aquatic mammals but also the grassland, scrubs and orchards for other species. Wetland dependent species are Mongoose and fishing cat, and other carnivores. Rats and mice prefer grassland and scrubs around the wetland; flying insects attract the bats. A study conducted around the middle of 1960’s in the Calcutta cluster of wetlands has recorded 22 species of mammals, representing shrew (1 species) bats (9 species), carnivores (7 species), squirrel, rat and mouse (5 species). A more recent study recorded 22 species of mammals, representing carnivores (10 species), squirrel, rat and mouse (9 species), bats (3 species).

5.1.4 Conclusions

Concluding all of the information that we have collected from all of our experiences about the East Kolkata Wetlands we can say that they are not only a very important part for the city sewage in that region. They also represent a special aquatic ecosystem and provide affordable food to a lot of poor people living in these regions. So, the East Kolkata Wetlands are very important for the wellbeing of many habitants of the region. Preservation of that region is, thus, of mere significance and will represent a challenge especial for the young generation such as students like us.

5.2 The Wadden Sea of Cuxhaven

5.2.1 Abstract

This scientific report introduces the Wadden Sea. We found out about what kind of role this aquatic ecosystem plays on the planet earth and compared it to other ecosystems. Upon an excursion we could find out how the Wadden Sea ecosystem generally functions. We inquired about the animals and plants living there, how the food chain is structured and how the ecosystem developed over the years as well as in which sense humanity impacted the system.

5.2.2. Introduction

The Wadden Sea is a very unique place on earth. It runs about 450 km on coastlines from the North of Denmark over Germany to the Netherlands, and it is habitat for a lot of birds, fish, different mammals (consumers) and plants (producers), but is basically influenced by the tidal flats giving best conditions for life in general but also for decomposers living in the mud (Nationalpark Wattenmeer, 2010).

Because of these reasons and the connection of the system to the sea (i.e. the North Sea), fishing became popular, thus, many people settled on the coastline.

The city of Cuxhaven represents the most northern part of Lower Saxony where the estuary of the river Elbe meets the North Sea. Thus, human activities not only comprise fishing but also shipping, e.g. from the harbor of Hamburg to the Sea. Additionally, the region along the coast is very prominent for agriculture and, also for tourism. As many agricultural ditches lead into the Elbe as well as the Wadden Sea, values of phosphate, ammonium, nitrate and nitrite were analysed to determine the supposed human impact.

Together, the following questions were addressed:

- How is the Wadden Sea structured and does it function as an aquatic ecosystem (water based ecosystem)?

- What kind of similarities and differences can be found when comparing the Wadden Sea to other ecosystems, e.g. the East Kolkata Wetlands?

- How is the influence of human activities along the coast?

- Is there any influence of the climate change on the Wadden Sea ecosystem?

5.2.3. Discussion

5.2.3.1 What is the Wadden Sea?

The Wadden Sea is a coastline area along the coasts of Denmark, Germany and Netherlands. It spreads over an area of about 10,000 km² with a length of 450 km and it stretches up to 40 km into the sea. The Wadden Sea is famous for the mudflats, which is one of three sub-habitats it contains. The other habitats are salt marshes and dunes. Many different animals and plants are living there (Nationalpark Wattenmeer, 2010). Together all of these factors form an ecosystem, which is way different than the East Kolkata Wetlands also being an aquatic ecosystem as well.

5.2.3.1.1 What are the climate conditions in the Wadden Sea?

As part of the coastlines of Denmark, Germany and Netherlands the Wadden Sea is located in the temperate zone. The temperate zone features are average temperatures from 0°-20°C, a precipitation from 300 to 2000 mm, with an average of 800 mm. According to that one might expect that there are no weather extremes. However, considering the fact that the Wadden Sea is on a coastline, which means that heavy onshore and offshore winds are developing, and parts of it (mudflats / tidal flats) are extremely affected by the changes of tides and especially by storm tides, the expectation answer to this is wrong: In comparison to other regions in the temperate already a "normal day" in the Wadden Sea can be described by wind, some clouds, rain and sunny weather (Nationalpark Wattenmeer, 2010).

5.2.3.2 The three sub-habitats of the Wadden Sea

Mudflats and tidal flats are the areas that are covered by the sea at high tide and left exposed to the air at low tide. Tidal flats make up two thirds of the entire Wadden Sea. Because of the constantly changing tide the animals and plants are subject to constantly changing abiotic factors, thus, have to be very tough (Seaworld Parks, 2019). The basic appearances of life in this habitat are different kinds of algae (mainly diatoms), which provide better air conditions by photosynthesis and a general

nutriment for animals. Iconic animals from this habitat are lugworms, which are causing the famous parcels on mudflats, lots of different mussels, from which you mostly just find the broken shells after they have been hunted by seagulls, etc., cancers (also sometimes found broken up because of hunting reasons) and various species of birds. Birds are usually not living in this habitat, but they're hunting for lugworms, mussels and cancers in the mudflats – the Wadden Sea thereby being their necessary food reserve especially on migration (Nationalpark Wattenmeer, 2010).

Saltmarshes are connecting onshore and offshore areas. This habitat provides special challenges for animals and plants living there because saltmarshes are getting flooded with saltwater 10-250 times a year leading to an extremely high salinity. About 400 species of insects are living there among the saliniforme plants. Those have evolved special metabolic adaptations to deal with the overload of salt. (Nationalpark Wattenmeer, 2010). Saltmarshes are also the breeding ground for lots of native birds. Dunes usually are formed on the East & North side of an island by the wind. The wind blows sand particles on the top layers and causes the sand to stack over a lot of time (because of this dunes are able to travel over some time). Dunes are held together by deep rooting plants.

5.2.3.3 Life inside and on top of mudflats/tidal flats (biotic factors)

5.2.3.3.1 Various algae and microalgae (unicellular-organisms)

Microalgae (unicellular organisms) can be found on the top layer of tidal flats as a brown slimy surface. Despite this colour, which is not green, they are carrying out photosynthesis. Thus, they convert carbon dioxide (CO_2), released by mammals' respiration, into oxygen (O_2) and they keep the carbon (C) for their own energetic recovery. The algae found in the Wadden Sea mainly belong to the group of diatoms that exists in a huge variety of shapes (Fig.5.3). Diatoms have a cell case build of silicone dioxide (SiO_2).

Fig. 5.3: Electron microscopic picture of a diatom showing the silica shell; colouring artificially by computer (National History Museum, London, n.d.)

Here (Fig. 5.3), the diatom has the shape of a star. Further possible shapes are *Centrales* (similar to triangular) and *Pennales* (rod-shaped), (Wikipedia.org).

5.2.3.3.2 Clams (example: blue mussel, *Mytilus edulis*)

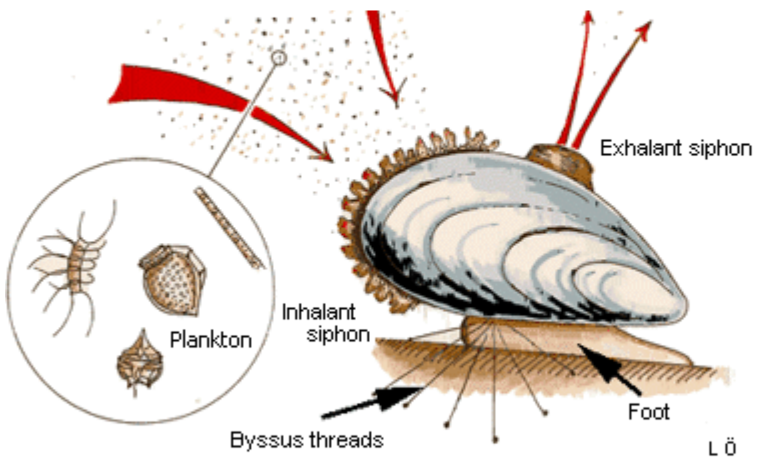


Fig. 5.4: Respiration and nutrition of the blue mussel *(Mytilus edulis)*, (Nordsieck and Eleveld, n.d.)

The picture (Fig. 5.4) shows the simplified metabolism of blue mussels. Their easily damaged body is protected by two shells, which are built mostly of calcium carbonate ($CaCO_3$). Most of the blue mussels are able to hide between their shells and lock themselves up in order not to get eaten by natural predators, for example sea gulls. Their part in the ecosystem is to clean the water (Fig. 5.4) by filtration – a process that also serves them for respiration and their own nutrition. Additionally, they serve as a food source for native birds (Nordsiek and Eleveld, n.d.). Thus, blue mussels, together with many further species of clams, are an inherent part of the Wadden Sea and they are also famous for being a dish.

5.2.3.3.3 The Lugworm (*Arenicola marina*)

Another prominent species found in the Wadden Sea is the lugworm, which lives in the silt of the Wadden Sea. It belongs belongs to a group of fixed and digging lines within the annelid worms known as sedentary (Wikipedia.org).

It digs up the 20 cm of the tidal flat, feeds on silt and excretes it. This way it digs himself through the silt, while during that time, it metabolizes residuals of plants, algae and plankton. This process moves nutrients from lower parts within in the silt up on the surface.

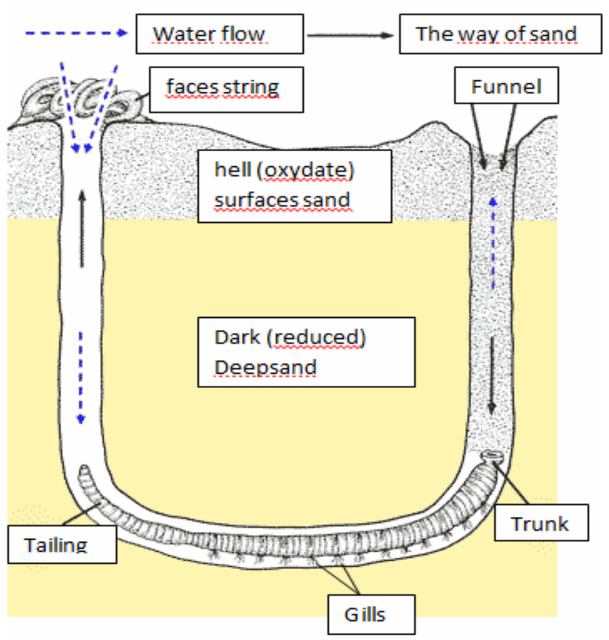


Fig. 5.5: U-shaped tube of a lugworm within the sediment showing the direction of water flow through the tube (Knor, 2005)

The Lugworm digs a tube into the mud that is shaped like a "u". He got there two ends: On the left site he excretes the silt and on top the faces accumulate as a string. On the right site he got a funnel for ventilation. He sucks in the silt with the trunk which than passes through its body for its nourishment (Knor, 2005). A water flow through the tubes goes into the opposite direction to the sand flow (Fig. 5.5).

The Lugworm represents a mayor part of the ecosystem of the Wadden Sea as it metabolises residuals of plants, dead animals, feces, etc. Without these worms and their activities we would have a higher production of manure gas in the Wadden Sea as this function would have to be covered by other decomposers, e.g. saprobia.

Also, a main function of the lugworm is to change and mix the individual layers of the sediment. Thus, the continuous mixture of layers leads carries nutrients to the top of the tide flat, which, in turn, can be taken up by the plants (diatoms) and animals and allows for ventilation of the Wadden Sea (Bernhard Rauhut, director of the Wadden Sea center Cuxhaven, pers. com, 2019).

When the lugworm is in a dangerous situation for example a bird manages to grab the tailing of the worm, than he can separate his tail and he can reform the missing part (Bernhard Rauhut, pers. com). That way, it can survive a predator attack.

If we thought just a second about a life without the lugworm – at first sight an unimpressive creature- we would recognize that the whole ecosystem wouldn't function and we would have an even bigger problem with greenhouse gases, because we have no ventilation that would prevent the emergence of gases such as methane.

5.2.3.4 How did the Wadden Sea get formed - a short explanation

The water of North Sea is carrying particles of sand and mud. This wavy water is getting calmed by islands near the coast and sandbanks, e.g. the East Frisian Islands. As the water is calmed the particles of sand and mud cozuld sink down to the bottom, where the particles accumulated. This process took place for lots of centuries. Rivers and their estuaries carry new sediment particles (Knor, 2005). By the time this assemblage became a habitat for lugworms, which constantly feed from the ground (filtering nutrients). Their excrements are known as “Watt” (the typical ground of tidal flats at low tide).

5.2.3.5 Water qualities in the Wadden Sea and North Sea

The water quality of the North Sea is basically influenced by the entering rivers, such as the Elbe and small agricultural ditches leading into the Elbe as well as into the Wadden Sea area. Human acitivities, thus, have a major impact on the water quality of the Wadden Sea. On the other hand, the tides carrying water from the North Sea allow for a constant mixing of the water masses that cover the mudflats during high tide and remain within tide creeks during low tide. To get information about the water quality in the Wadden Sea we made different experiments on different water samples from tide creeks in Wadden Sea and the river Elbe. We tested for the content of phosphate, ammonium, nitrate and nitrite by using a common test box (Tab. 5.1), minerals, functioning as nutrients which usually represent a common problem in agricultural areas.

Tab 5.1: Values of different minerals obtained from water analyses

	phosphate	ammonium	nitrate	nitrite
Tide creek Wadden Sea	0.175 mg/l	0 mg/l	0 mg/l	0 mg/l
River Elbe	0.33 mg/l	0.166 mg/l	0 mg/l	0 mg/l

These parameters provide information about life conditions for the appearance of life at this place and possible effects on fish industry (for more detailed information see chapter 8). It can be concluded that the Elbe indeed is responsible for an input of nutrients / minerals into the Wadden Sea and the North Sea. Apparently, the mixing of the water because of the tidal changes together with the enormous activities of the Wadden Sea organisms, such as lugworms and clams, might lead to a notable

reduction of these parameters in the tide creeks (Tab 5.1). This, in addition, might also positively affect the water quality of the North Sea.

5.2.5.1 Wadden Sea UNESCO world heritage since 2009

On 26th of June 2009 the Wadden Sea has been appointed as a world heritage of nature by the UNESCO. Besides its uniqueness the Wadden Sea also provides a lot of advantages for settlers: It provides best conditions for fishing and its reproductive grounds can be used for growing of fish or clams. Also, many settlers gain their money from tourism. These and lots of more parameters make the Wadden Sea a humanitarian environment. To prevent this special place from human effects, like overfishing, the Wadden Sea has been appointed as one of the UNESCO world heritages. The protection of this special ecosystem, as well as a sustainable cooperation of human activities and nature is controlled by the rules of the Nationalparks and the Biosphere reserve. The certificate of the Amandus Abendroth Gymnasium Cuxhaven as “Biosphere school” contributes to this cooperation.

WATTENMEER
WELTNATURERBE

Organisation der Vereinten Nationen für Bildung, Wissenschaft und Kultur

Das Wattenmeer Welterbe seit 2009

Fig. 5.6: Labels of the UNESCO World Heritage of the Wadden Sea (left, Nationalpark Wattenmeer, 2010), picture of Dhrubajyoti Ghosh, a scientist who investigated the Kolkata Wetlands and fought for their declaration as RAMSAR site (right).

In comparison, the Kolkata wetlands have been declared as a RAMSAR SITE by the RAMSAR convention, which was meant for protecting wetlands in general. An important name during the fight for protection of these wetlands is *Dhrubajyoti Ghosh* (Fig. 5.6).

5.2.4. Conclusion

We can say that the Wadden Sea is naturally a well working aquatic ecosystem. The tidal flats host a lot of important decomposers, for example the lugworm. The tidal flats also provide a well-balanced protection for the prey of sea gulls and other consumers, which are mostly various birds living in the saltmarshes. These birds feed from lugworms and mussels. Further consumers in the Wadden Sea are North Sea fish whose offspring grows in the Wadden Sea area, seals feeding on fish, as well as different species of cancers (Wikipedia.org.). Microalgae such as diatoms provide the Wadden Sea's residents with oxygen for respiration.

However, two main dangers the Wadden Sea is exposed to have to be elucidated:

One is overfishing: When people catch too much fish, the amount of living fish could decrease so the seals will have less fish to feed on. That means that we will have less seals in the North Sea after some time. The effects of this process can already be seen. Seals play an important role in the food chain so the missing of seals could bring the balance apart. In turn, that means that humanity replaced the job of the seals in the food chain and if humans go on overfishing the sea the balance will be brought apart.

The second one is shipping: The river Elbe is used a lot for shipping reasons, the used ships had become bigger all over the years. That also means their draught increased and so necessary measures have been adopted. The river Elbe, which is itself a habitat for a lot different animals but also is directly connected to the Wadden Sea ecosystem, has been digged deeper to make possible more efficient shipping. Because of the fact that many ships pass the river Elbe and the Wadden Sea each day, many natural processes can either not happen or are at least affected by the excessive shipping.

Finding a solution for these two main problems is hard, because the harbour of Hamburg is of major importance for import and export of German goods, providing jobs to many people. So, this cannot be stopped as the effects would be too big. – Solving this economic-ecologic conflict is, thus, an immense challenge.

Maybe it could be possible not to overfish the Wadden Sea, because most of the fish, which is consumed around the coastlines of the Wadden Sea, is imported by others countries. The long distance transport is adding another ecological problem to the situation – the release of climate gases. However, consequent regulation and control of the fishing amounts can solve the problem at least on the long scale. The MSC label is a beginning to solve the problem. A change in the mind of the human consumers might be another important factor.

6 The effort of water abstraction and purification in Kolkata, India

6.1 Abstract

Fig. 6.1: View over the East Kolkata Wetlands (photo: Breuer, 2019)

The present report deals with the efforts necessary to remediate wastewater in the East Kolkata Wetlands. From this, four questions were derived and answered. After discussing water contamination, the efforts themselves and several maintenance factors, the following conclusion was drawn: The East Kolkata Wetlands are in need of a high level of maintenance efforts. These efforts are in the end counterbalanced by the highly beneficial natural circumstances as well as the self-sufficiency of most of the implemented procedures. Heavy metals and algae are efficiently cleaned out of the water and fish as well as rice is produced en masse. At the end of the cleaning cycle the purified water is not drinking water and has to be fully treated elsewhere.

6.2 Introduction

6.2.1 Basic ideas

Water is a basis of every effort to obtain and preserve a civilization. But it only unfolds its entire potential if it's sufficiently cleaned. Unclean water will spread diseases by making basic hygiene impossible, cause infections if used in e. g. surgery and in the long run shorten the life expectancy of everyone who consumes it on a regular basis. *Vice versa*, clean water will improve the lives of all who come in contact with it, quenching their thirst without negative side effects as well as sufficiently cleaning medical instruments, wounds and bodies. To implement water purification and abstraction into a nation's system adequately, the effort of maintaining these procedures has to be minimized for the sake of efficiency. This will make clean water available to more and more people.

Hence, this report seeks to evaluate the amount of effort put into cleaning wastewater in the region of Kolkata, West Bengal in India. If possible, inefficiencies will be pointed out and constructive solutions will be presented.

6.2.2 River Ganges/Hooghly River

The river Ganges/Ganga flows through both the nations of Bangladesh and India. Its length is 2,525km. It rises in the western Himalayas and generally flows southwards. One the one hand it is regarded as sacred and purifying by the Hindu population, on the other hand it is heavily polluted by various sources, ranging from trash to religious offerings, sewage and by poor people, who use its water to bathe and wash (see above, Wikipedia Org. 2019). Measures to clean the river, which is highly important for the country's water supply, have been taken but weren't very successful up to this day (Kuntz, 2016).

In the region of West Bengal, the river splits into two distributaries: the rivers Padma and Hooghly. Kolkata and the region around it are mostly dependent on the Hooghly River for water supply. Sewage water recycled in the East Kolkata Wetlands is led back into the river (Wikimedia Foundation Inc., 2019; also see the report above).

6.2.3 East Kolkata Wetlands

The East Kolkata Wetlands are an artificially modified aquatic ecosystem located in the city of Kolkata, West Bengal. Generally speaking, wetlands are characterized as regions that are regularly flooded by water. Thus, there are diverse types of life that have developed in and adapted to that habitat. Also, wetlands allow for farming of vegetables and different types of animals, dependent on the climate and nutrients present.

The East Kolkata Wetlands are a very special example. Their properties are used in a systematic effort to clean sewage water and use its nutrients. The wetlands are flooded with sweet wastewater. The algae and nutrients present are used for fish

farming as well as fertilising vegetable and paddy farms. Also, there are many plants present which clean the water from e. g. grease, oil and heavy metals by means of their metabolism. After being filtered like this, the water is released back into the Hooghly River.

Hence, the East Kolkata Wetlands partake in the large scale production of food whilst also purifying large amounts of waste water in a way, that utilizes the natural processes already present without harshly disturbing the ecosystem (Ghosh, 1999).

6.2.4 Water abstraction/purification plant Serampore

The water abstraction and purification plant located nearby Serampore, West Bengal, pumps water out of the Hooghly River and then purifies it in various steps. The water is freed of germs and toxic contents before being delivered to the population of seven towns of the region. Water abstraction plants like these are of big importance, because only 20 to 30 % of the drinkable water used in households in West Bengal is derived from ground water. Hence, most of the water that's purified is surface water such as river water (Basu, 2015). The plant was deliberately constructed at a place, where the water was less polluted than in the others. Containing diverse laboratory equipment, water testing measures are regularly conducted in the plant to check and improve the drinking water's quality.

Together, there are 5 active plants similar to Serampore responsible for providing Kolkata and the surrounding region with drinking water.

6.2.5 Aims & main objectives

As already stated, this report wants to evaluate the efforts undertaken to abstract and purify water in the region of Kolkata, West Bengal. The main questions that are derived from this can be stated as follows:

- Which efforts and labour are necessary to produce the drinking water and clean the wastewater of the described region?
- Which kind of contaminations have to be purified from the wastewater?

- Which processes take place in the East Kolkata Wetlands to purify the wastewater?
- How are the water purifying sites in the East Kolkata Wetlands taken care of?

6.3 Discussion

We visited the Water abstraction plant in Serampore (Fig. 6.2) and talked to the water expert present at the moment for research purposes. Also, we visited the East Kolkata Wetlands with the same goal.

Fig. 6.2 Visit of the water abstraction plant Serampore (photo: Breuer, 2019)

To deduce the amount of labour utilized for these processes, we'll use economic factors such as amount of time taken, land use, expenses, number / type of machines, purity of water and number of processes. To show which efficiencies and inefficiencies are present in the current method we compared it to other methods.

6.3.2 Description of observed water purification processes/sites

6.3.2.1 Description of Water abstraction/purification plant

The water treatment plant at Serampore produces 90 million litres of water per day bearing the responsibility of supplying portable water to seven towns within the region around Kolkata.

The aims of the plant are:

1. **Reducing turbidity** of water to less than 1 NTU (Nephelometric Turbidity Unit).
2. **Destroying all microbes** and harmful chemicals in the water. It uses several processes like:
3. **Abstraction**-The process of drawing water from the river.
4. **Pre-Chlorination**-Addition of chlorine to kill germs.
5. **Foam Formulation**-Separation of slag from the water.
6. **Clariflocculation**-The process of colloidal sedimentation.
7. **Filtration**-Removal of impurities using sand, grains and gravel.
8. **Storage**-Storage and distribution of purified water.

There are two laboratories in the plant that test the water for bacteria and chemicals.

Totally, the water treatment plant purifies 90 million litres of water on a very large scale employing large amounts of machine and labour, making the entire process very cost intensive (Basu, 2015).

6.3.2.2 Description of a comparable filtration experiment

In contrast to the above described processes that take place in the plant Serampore, a simple filtration experiment can purify water. Layers of stones, gravel and sand are used to filter undissolved particles and organic matter that are responsible for the turbidity. Impure water also contains hardness (soluble salts of chloride and bicarbonates of calcium, magnesium etc.) which is removed by zeolite. The latter also removes the ammoniacal smell. The colouring agents and odour are removed by activated charcoal. Finally, chlorine water removes germs. Thus, a filtration unit can be made of zeolite, charcoal, sand and gravel which filters impure water. The water obtained is deemed pure after chlorine is added. This simple process can be carried out at home on a small scale. Only readily available materials need to be used. Also, it is not very cost intensive (for further details concerning the procedure see chapter 8).

6.3.3 Application of the East Kolkata Wetlands for sewage treatment

6.3.3.1 Description of the artificially modified ecosystem “East Kolkata Wetlands”

The East Kolkata Wetlands (short: EKW) are a 12500 hectares large artificially modified ecosystem.

The basic definition of a wetland is that the ecosystem in question is periodically/regularly flooded by water. It is home to over 100 types of plants as well as many different types of fish, mainly carps. Non-human-modified kinds of sub-habitats include salt marshes and salt meadows, because the water derived from the Ganges is salty in this region.

The unique characteristic of the East Kolkata Wetlands is that, additionally to the regular water supply by the Ganga/Hooghly River, sewage and wastewater is led into the region. This serves several functions: One is agriculture. The algae and polluting contents of the water such as different nutrients can be used to fed fish. The process works like this: The main species of bacteria present in the sewage water are *E. coli* bacteria. These bacteria produce carbon dioxide by their cell respiration, which, combined with sunlight naturally entering the ponds, helps to grow the algae necessary to keep the fish nourished. Big fish ponds are called *bheris*, small, trench like ones are called *jheels*. Currently, there are 264 fish farms occupying roughly 3000 hectares of surface area, i.e. roughly one fourth of the total area of the wetlands (Gupta, pers.com).

On the other hand, the EKW function as a purification system for the city sewage. Not only do the fish extract algae and several pollutic compounds from the water, but several types of plants nurture off and filter the sewage, for example the *Eichhornia crassipes*. This stabilises the ponds ecosystem as well as contributes to the filtering of the water. Plants like these clean the water also from grease, oil and heavy metals.

All of these processes are self-maintaining in such a way, that the highest costs in the EKW are the wages of workers maintaining the processes and farming the products (Ghosh, 1999).

6.3.3.2 Disadvantages of wetlands

Although most of the processes taking place in the EKW are self-sufficient to an extent that allows for low-labour-profits, there are certain disadvantages of wetlands as an ecosystem one has to take into account. These are generalized. Mechanisms against disadvantages that are already used in the EKW will be pointed out.

One main disadvantage of wetlands is that their nutrient- and water-rich habitat accompanied by a fitting climatic circumstance will easily allow for breeding of diseases. In regard to bacteria, the *E. coli* bacteria present in EKW water don’t allow for other kinds of bacteria to spread (Gupta, pers.com). These *E. coli* bacteria themselves are, however, integral to the cycle that leads to fish production, as discussed above.

Another disadvantage of wetlands is the enormous amount of land used by such an ecosystem. This problem is one of the biggest threats to the EKW as Kolkata’s population has been growing in such an amount that leaving an area as large as 12500 hectares almost entirely unused for purposes of housing people seems like a luxury to some voices in business and politics (Gupta, pers. com). Altogether, a social and economical dilemma.

Although the waste water treatments taking place in the EKW mostly take place in relative harmony considering the environment, wetlands in general have a long history of producing large amounts of methane. In fact, 25 % of the world’s methane is produced by wetland ecosystems (Wikipedia.org). Methane has been described as being 25 times more effective than carbon dioxide concerning the greenhouse effect (Dambeck, 2019). Thus, the anti-smog effect and low carbon dioxide emissions of the EKW’s described above might be elusive concerning the ecosystem’s net effect on climate change. Comparative studies are missing so far.

Plants, water plants and algae, might filter some substances out of the air and reduce overall carbon dioxide amounts present. But they might be useless against a lot of pathogens that might be present in the water. Although it is expected that *E. coli* bacteria prevent the development of other microbes that might or might not be pathogenic, nobody really has investigated this topic, so far. Also, *E. coli* themselves can become pathogenic if present in certain amounts which are not supervised. The uselessness of the different kinds of plants might be true in respect to highly toxic contents in the wastewater that the natural processes can't deal with. Those might arise from medical drugs or other chemicals introduced into the water by human or industrial activities. Also, microplastic particles nowadays representing a major problem in almost all waterbodies of the world (Carrington, 2019) might be contaminants within the wastewater of Kolkata. On the one hand, this concern is quite serious as these contents would be directly introduced in the food production in numerous occasions. On the other hand, the wetlands already take care of a surprisingly wide array of pollution. Also, the EKW are not the last step taken in cleaning the water. Before being available to any homes or industries, the water will be led back into the Hooghly and pumped through a water abstraction and purification plant like the one in Serampore. There are five of these plants which are directly responsible for the city of Kolkata (Kielmas, 2018).

6.3.3.3 Deduction of the relative amount of labour

Comparing the processes of water purification in treatment plants and the chemical experiment (details see chapter 8), we see that the filtration unit uses readily available materials and can be performed by anyone easily, while the plant utilizes elaborate and complex machines and around 80-85 labourers. The EKW use a lot of already present environmental processes to purify water (which is only possible if such an ecosystem is available). However, there are workers needed to harvest the fish and vegetables as well as maintaining their ideal growing circumstances. The employment necessary is huge; at minimum the 264 fishing companies must be maintained. The land mass used ranges around 12500 hectares, which is huge. A large channel system, various pump stations and treatment sites are necessary.

The model experiment (chapter 8) uses just one process of filtration while the plant performs 6 processes and several tests. There are mainly two processes of sewage treatment used in the EKW.

The plant produces 90 million litres of drinkable water water, utilizing several acres of land area, making purification a large-scale endeavour. On the other hand, filtration just produces 500 ml - 1 litre of pure water making it a small-scale project. In contrast, the EKW produce around 750 million litres of purified water a day, taking in a third of Kolkata's sewage (The Hindu, 2016).

Water treatment plants require a lot more investment and purification time than the simple filtration, which is more economic. Despite their excessively large scale and labour needed for maintenance, the usage of environmental circumstances already present and the implementation of profit-oriented structures in the EKW have led to relative economic efficiency.

The water abstraction plant produces totally pure potable water, which is relatively safer than water obtained after a simple filtration process. The EKW wastewater is cleaned of heavy metals, oils, grease, other toxic contents, unneeded nutrients and algae by *Eichhornia-crassipes*-rhizofiltration. *E. coli* bacteria are not taken care of, as are highly toxic materials.

Thus, we see that intense effort in terms of time, money, labour and land area is required in plants as compared to the experiment. The East Kolkata Wetlands use an exorbitant amount of workers and land area. From another perspective one could also say they provide lots of jobs and produce food affordable also for the poorer population. They also produce exorbitant amounts of relatively clean water and can hence be deemed very economic (Li *et al.* 2018).

6.3.3.4 Estimation of contaminations present in Kolkata's sewage water

Because of the lack of data concerning the contamination of Kolkata's sewage water, we focused on the water that is led into the EKW before and during rhizofiltration / remediation. This is the utmost amount of precision we could achieve.

The main processes of remediation of this type of wastewater described by research concern the removal of toxic heavy metals from the water. We'll hence focus on these and the amounts in which they are present. Ms Gupta, our guide in the EKW-tour, pointed out that there is no clear data on the presence of microplastics and medication contaminating the wastewater. Despite this ambiguity, she assured that the amounts of both range from "not harmful" to straight up negligible.

By contrast, Khatun *et al.* (2016) investigated the amounts of several heavy metals in the sediments as well as the roots of plants. They found concentrations in in sediment "from highest to lowest, Mn (205.0 ± 65.5 mg/kg) > Cu (29.9 ± 10.2 mg/kg) > Pb (22.7 ± 10.3 mg/kg) > Cd (3.7 ± 2.2 mg/kg). [...] The rate of accumulation of metals in roots was higher than in shoots. There were strong positive correlations ($p< 0.001$) between soil organic carbon (OC) percentage and Mn ($r = 0.771$), and sediment OC percentage and Pb ($r = 0.832$). Cation exchange capacity (CEC) also showed a positive correlation ($p< 0.001$) with Cu ($r = 0.721$), Mn ($r = 0.713$), and Pb ($r = 0.788$), while correlations between sediment OC percentage and Cu ($r = 0.628$), sediment OC percentage and Cd ($r = 0.559$), and CEC and Cd ($r = 0.625$) were significant at the $p< 0.05$ level.“ One can assume that besides this observed bio-accumulation of heavy metals in plants further accumulation might take place within the food chain, thus, in the plant-feeding fish, and, in consequence, in the fish feeding human.

Concerning bio-contamination, there are first and foremost various algae present in the EKW's water. Additionally, there are *E. coli* bacteria present in the wastewater. According to Ms Gupta, the presence of *E. coli* bacteria indicates, that no other type of bacteria can grow (Khatun *et al.* 2016).

6.3.4 Description of some purifying processes taking place in the East Kolkata Wetlands

6.3.4.1 Description of water remediation by rhizofiltration

Fig. 6.3: Water hyacinths a.k.a. *Eichhornia crassipes* (Dühmke, 2009).

The water hyacinths, (species: *Eichhornia crassipes*) purify the water from various heavy metals and other toxic material. Some of these heavy metals include copper, lead, zinc and cadmium (Li *et al.* 2018) as well as chrome. The plants' roots reach into the EKW water as well as into the ground. Hence, water is taken in by the roots. The particles of the heavy metals in question are adsorbed by the roots' biomass (Cao *et al.* 2019). The nutrients vital for the plants' survival are taken up from the ground the plant rests on.

Eichhornia crassipes is perfectly adapted for such a function because of its high biomass growth rate, replacing and regrowing new body tissue efficiently. This way, the toxic material can be bound for a long time without the plant taking damage. For instance, experiments show that the plants filter around 99.95 % of chrome out of prepared water (Saha *et al.* 2016). They also filter excessive amounts of unneeded nutrients out of the water counteracting a possible eutrophication. This kind of water remediation by using plant roots is called rhizofiltration (Li *et al.* 2018).

6.3.4.2 Description of water remediation by the food web of the fish ponds

The only kind of bacteria present in EKW wastewater are *E. coli* bacteria (Gupta, pers. com). Like every living organism they produce carbon dioxide by cellular respiration (Williams, 2011). The same holds true for the fish. The carbon dioxide released to the water is then taken in by algae. When sunrays enter the water, these algae grow by photosynthesis, binding and creating nutrients in this process. Also, photosynthesis produces the oxygen the *E. coli* and the fish need continuously. On the other hand, the algae consume nitrate and other minerals that are released by the metabolic activities of the bacteria when decomposing the faecal impurities of the wastewater.

Hence, there are a lot of algae growing in the channels and fish ponds of the EKW. These algae are consumed by the fish present in the two types of fish ponds, the *bheris* and *jheels*. Thus, the fish are fed and the water is cleaned from the substances that have been taken up by the algae before but also from an overproduction of algae (Ghosh, 1999).

6.3.5 Description of the efforts and labour needed to maintain purifying sites in the East Kolkata Wetlands

Although the wastewater purification of the wetlands refers to a natural process that is self-sustaining four categories for critical maintenance of the so called *bheris* have been pointed out:

“a) Maintenance of the required depth of water at all the three stages of the production process e.g. at nursery pond, rearing pond and stocking pond with proper inlet-outlet management of sewage.

b) Availability of quality spawn/fry/fingerlings at required time and quantity.

c) Proper and efficient deployment of working personnel, ensuring satisfactory labour productivity and congenial labour relations.

d) Monitoring fish health” (Ghosh, 1999).

6.4. Conclusion

In conclusion, we can answer the questions stated in the introduction as follows:

The efforts of producing drinking water in Kolkata involve not only pumping the water out of the Ganga and then treating it chemically. The wastewater is led into the 12500 hectars large East Kolkata Wetlands through a channel system and there it is purified in established, commercial fish ponds and garbage farms as well as by the already present flora. Hence, not only does there need to be several pumping and purification stations as well as channels, but also a large ecosystem has to be maintained. The same counts for the large amounts of jobs that are provided by the fish ponds and garbage farms. This effort, which at first seems quite huge, is minimized by several circumstances. Not only is the water efficiently cleaned in respect to faecal residues, heavy metal and algae pollution even before it has to be pumped out of water by a specific plant, saving time and effort. Also, the processes used in the EKW water remediation efforts are either naturally present (e.g. the *Eichhornia crassipes*, which clean the water and stabilise the *bheris'* walls) or self-sufficient (fish-*E.coli*-cycle). The general disadvantages of wetlands could neither be proven nor disproven to take place in the EKW. Hence, the EKW are very fruitful in regards to food and clean water production. Hence, they balance out on disadvantages like not entirely cleaning the water and the costs of maintaining large-scale pumping station and channel complexes.

Most of the pollution that's dealt with in the EKW refers to different types of industrially used heavy metals like copper, lead, zinc and cadmium as well as

chrome. Bio-pollution is limited to various algae and *E. coli* bacteria. The *E. coli* bacteria, according to Ms Gupta, have the property of usurping other bacteria.

The most important procedures of water remediation in the EKW are rhizofiltration and the fish's feeding on algae. Rhizofiltration is largely based around the *Eichhornia crassipes*, which bind heavy metals, grease and oils in their roots whilst maintaining nutrition from the ground they're standing on. The remediation processes taking place in the garbage farms weren't dealt with. In the end, some of the polluting content in wastewater as well as garbage will be used to irrigate and fertilise paddy fields.

Regarding the garbage farms and pump stations, we are only able to speculate. Also, there is no clear data on the number of workers present in the entire EKW. The 264 commercial fish ponds present in the EKW (Gosh, 1999) have at least certain standards of maintenance: Water depth, spawn availability, efficient deployment of workers as well as fish health.

7 The effort of water abstraction and purification in Cuxhaven, Germany and Kolkata, India

7.1 Abstract

The report seeks to deduce the differences in effort and circumstances of water abstraction and purification between Cuxhaven, Germany and Kolkata, India. Also, the resulting water's quality was part of the research. For this purpose, a water abstraction and purification plant in Cuxhaven and Kolkata/Serampore as well as a sewage treatment plant in Cuxhaven and the East Kolkata Wetlands were visited and extensive research was conducted there. In the end, the effort of water abstraction and purification in Cuxhaven was deemed to be high and efficiently applied. The same counts for similar efforts in Kolkata. Differences in circumstance such as population size and sources of water were discussed. Main usage of "pre-filtered" ground water and less polluted bodies of water in Cuxhaven were found to be a beneficial circumstance in contrast to Kolkata, which uses the highly polluted river Ganges as a water source. The greatest difference between the processes both cities use to remediate water was found in the East Kolkata Wetlands. Instead of using an artificial sewage treatment facility, Kolkata remediates its water in this natural ecosystem that's close to a perfect fit for this task, using already present flora and fauna for a multitude of economic purposes including the water treatment. In Cuxhaven, this is not the case and the sewage treatment is almost entirely artificially conducted. However, both sewage treatments used bacterial nitrification as an essential part of the purification process. In the end, no significant differences in water qualities were detected.

7.2 Introduction

7.2.1 Basic ideas

Water is a basis of every effort to obtain and preserve a civilization. But it only unfolds its entire potential if it's sufficiently cleaned. Unclean water will spread diseases by making basic hygiene impossible, cause infections if used in e. g. surgery and in the long run shorten the life expectancy of everyone who consumes it on a regular basis. *Vice versa*, clean water will improve the lives of all who come in contact with it, quenching their thirst without negative side effects as well as sufficiently cleaning

medical instruments, wounds and bodies. To implement water purification and abstraction into a nation's system adequately, the effort of maintaining these procedures has to be minimized for the sake of efficiency. This will make clean water available to more and more people (United Nations, n.y.) The significance of this topic is also discussed and supported by international water law development by the UNESCO (UNESCO, 2003).

7.2.2 The city of Cuxhaven

Cuxhaven is a small city located in the most northern part of Lower Saxony. Gaining its city rights in 1907, the most economically important branches include the port, tourism and fishing. Also, wind turbine production is slowly gaining a stand. The name is used both for the city itself as well as for the county. The city, which is devided in 12 districts, has an area of 161.9 km^2 and is home to about 49.782 (status: 01.05. 2016) inhabitants. Being much larger, the county's area of 2,057.78 km^2 contains ca. 198,100 residents. Cuxhaven is surrounded by the mouthing river Elbe and the North Sea, which meet each other at the Northern peak of the city (Stadt Cuxhaven, 2019; Landkreis Cuxhaven 2019).

7.2.3 The river Elbe

Being one of Central Europe's largest rivers, the river Elbe rises in the Krkonose Mountains of the northern Czech Republic. After that, it flows through most of Bohemia (Czech Republic) to then mouth into the North Sea at the city of Cuxhaven in Lower Saxony. Its total length is 1,094 kilometres. As it for example passes by Hamburg's port shortly before entering into the North Sea, it is of great economic and cultural significance. The water quality in the estuary region is brackish, mostly caused by the continuous contact with the saltwater of the North Sea. However, its water quality is definitely distinguishable from the seas saltwater (Wikimedia Foundation Inc., 2019).

7.2.4 The North Sea

The North Sea is a marginal sea of the Atlantic Ocean. It is located in the northwest of Europe. The North Sea is limited by land on three sides and it is opened to the northeast Atlantic. The coast of the North Sea is 150 kilometres long and represents an important trade channel. The salinity level of the water along the coasts depends on the location and the season. The rivers of the North are carrying salt-water and the rivers of the East freshwater. The surface of the North Sea has the amount of 575.000 square kilometres and the total volume of the water amount to 54.000 cubic kilometres (Wikimedia Foundation Inc., 2019).

7.2.5 The city of Kolkata

Kolkata is the capital city of the Indian state of West Bengal. Kolkata has 4.5 Million inhabitants and is one of the biggest cities in India. The city is located nearby the river Hooghly which is a side arm of the famous river Ganges. The urban area covers 187.33 square kilometres (Wikimedia Foundation Inc., 2019, World Population Review, 2019).

7.2.6 The river Ganges/Hooghly

The river Ganges/Ganga flows through both the nations of Bangladesh and India. Its length is 2,525 km. It rises in the western Himalayas and generally flows southwards. One the one hand it is regarded as sacred and purifying by the Hindu population, on the other hand it is heavily polluted by various sources, ranging from trash to religious offerings, sewage and by the activities of poor people, who have to use its water to bathe and wash. Measures to clean the river, which is highly important for the country's water supply, have been taken but weren't very successful up to this day.

In the region of West Bengal, the river splits into two distributaries: the rivers Padma and Hooghly. Kolkata and the region around it are mostly dependent on the Hooghly River for water supply. Sewage water recycled in the East Kolkata Wetlands is led back into the river (Wikimedia Foundation Inc., 2019).

7.2.7 The East Kolkata Wetlands

The East Kolkata Wetlands represent an artificially modified ecosystem located in the city of Kolkata, West Bengal. Generally speaking, wetlands are characterized as regions that are regularly flooded by water. Thus, there are diverse types of life that have developed in and adapted to that habitat. Also, wetlands allow for farming of vegetables and different types of animals, dependent on the climate and nutrients present (See former chapters).

The East Kolkata Wetlands are a very special example. Their properties are used in a systematic effort to clean sewage water and use its nutrients. These wetlands are

flooded with sweet wastewater. The algae and nutrients present are then used for fish farming as well as fertilizing vegetable and paddy farms. Also, there are many plants present which clean the water from e. g. grease, oil and heavy metals. After being filtered like this, the water is released back into the Hooghly River.

Hence, the East Kolkata Wetlands partake in the large-scale production of food whilst also purifying large amounts of water in a way, that uses the natural processes already present without harshly disturbing the ecosystem (Ghosh, 1999).

7.2.8 Aims & Objectives of the present report

The main questions this report aims to answer are as follows:

1. How much effort is put into abstracting and purifying water in the city of Cuxhaven?
2. How are Kolkata and Cuxhaven different in the circumstances of these processes?
3. What methods are applied in Kolkata and Cuxhaven to abstract and purify the water and how do they differ from each other?
4. Which differences in water quality are due to the different processes being used?

7.3 Discussion

Upon our exchange program we visited the East Kolkata Wetlands (short: EKW), the water abstraction and purification plant in Serampore, the "Wasserwerk EWE" in Cuxhaven and the "Klärwerk EWE" in Cuxhaven to observe the processes used to abstract and purify the sewage water of Kolkata as well as Cuxhaven. The East Kolkata Wetlands as well as the "Klärwerk EWE" are used for sewage remediation. Abstraction and purification of tap water is done in the water abstraction and purification plant in Serampore as well as in the "Wasserwerk EWE". We'll compare these two topics separately. The effort will be deduced by using measures such as amount of time taken relative to the output, land use, expenses, number / type of machines, purity of water and number of processes. This method will show differences in method and their benefits as well as inefficiencies. If possible, solutions will be suggested.

All facts about the water abstraction plant in Serampore, the East Kolkata Wetlands, the "Wasserwerk EWE" and the "Klärwerk EWE" were taken directly from our respective guides there as well as the official websites of the respective plants.

7.3.1 Description of the processes and methods in the abstraction plant "Wasserwerk EWE" in Cuxhaven

7.3.1.1 Water abstraction in the "Wasserwerk EWE" in Cuxhaven

All information presented in this chapter was taken from the website of the Wasserwerk EWE Cuxhaven (EWE Netz GmbH, n.d.) and from pers. com of Frank Schmitt, who guided us through the plant.

The "Wasserwerk EWE" in Cuxhaven is located in the Drangstweg. It is used for abstracting and remediating groundwater to be used as drinking water.

The area used for gathering drinking water (protected by law from contamination) is 3000 hectares large and is going to be expanded to 6000 hectares within the near future. The average usage of groundwater for drinking water production in the entirety of Germany is 70 % (30 % surface water) while in Cuxhaven 100 % usage of water depends on groundwater.

For abstraction, 14 vertically filtering wells are connected by pipelines to 2 plants, 10 wells supplying the main plant and 4 wells supplying the emergency plant. The second plant represents a back-up that is only used for peaks in water usage. The wells work independently, i.e. one doesn't affect another water level- or pumping-wise. A volume of 100 m^3 per day can be pumped at maximum by one well. Water that has run through the steel and gravel filtering process of the well itself still contains iron and manganese, hence, the pH is at 6.5; which should be at 8 as slightly basic conditions are more suitable for the pipes. In one well there are five pumps out of which a big ones pump 300 cubic metres/h and the other small ones pump 150 cubic metres/h. The pump pressure itself lifts up the water to 4.65 m.

6,000-12,000 cubic metres / day of water are pumped throughout the year to cater mainly to the tourist demands. The maximum capacity of abstraction is 100,000 litres/ hour or 100m^3/d, taking the maximum capacity of the tanks at 14,000

dm^3/14,000 l per day. Calculating the amount, taking into account all the 10 wells used and their maximum performance being at 100 m^3/h spread over 24 hours, we reach a theoretic maximum output of 24,000 m^3/d. The plant's website however states, that the maximum output is at 15,000 m^3/d, a difference which could be caused by different well types being used. Not all wells are always used and almost never at maximum capacity.

Up to now, there are no problems of water shortage that is expected for various regions at the North Sea coast because of salinization of groundwater reserves due to the rise in the sea level as a consequence of the climate change (IPCC, 2014) However, if the situation becomes extreme, also in Cuxhaven wells will have to be dug deeper and the entire process will be adversely affected. At present, the wells are dug as deep as 43 m, the layer of filtering soils start at a depth of 25 m. The diameter of the wells is roughly 1 m and different sands, steel and gravel are used to filter the water. The soil is a barrier to surface water (10 m-14.5 m).

The pressure on water is 4.3 bars at release of the plant and 4 bars when it reaches the consumer's home. Two transformers are used to maintain the plant. Also, a generator can power the entire plant for a day if the main power supply of the city stops working.

7.3.1.2 The filtering and purification processes

From the wells the abstracted water is pumped to the plants where it is further purified in huge filtering tanks. One filtration tank contains 60 tonnes of filtering material ($CaCO_3$/calcium carbonate). The tanks are 6 m high, and 4.5 m in diameter.

Fig. 7.1: Schematic overview of the different processes conducted in the Klärwerk EWE Cuxhaven for gaining drinking water (photo: Keuser, 2019)

Briefly, the unwanted manganese and iron in the abstracted water are oxygenated by aeration so that they can be filtered out as solid particles. This is how the dilution of both metals is reversed. CO_2 is shaken out together with the aeration and by mechanical processes. At this stage, the pH is higher, that is, from 6.5 it is converted to 7.2. Oxygen is led up from the bottom to the top through the tank containing the water. Shaking of the water turns it into droplets, which enlarges the surface area and makes oxygenation easier. This process increases the oxygen value of the water from 0 mg/l to 10 mg/l. Furthermore, $CaCO_3$ is used to bind H_2CO_3. Thus, the water becomes even more basic - that is a pH of 7.9 to 8.

The entire filtering process takes 20 minutes and comprises five different steps:

1. The water is pumped out by the wells into the plant. Because of the ground composition as well as the filters present in the well the water already gets rid of some contamination.
2. Then the water is trickled. Aeration from below leads to oxygen enrichment (acidification), CO_2 getting blown out (deacidifcation) and iron and manganese getting oxygenated and filtered out (deacidification). This is called “trickling- and filter-street”.
3. Then, further filtering with $CaCO_3$ leads to H_2CO_3 getting filtered out, which leads to the final deacidification. This is called “Post-deacidification”.
4. The finished water is stored in special tanks and controlled for certain parameters as stated below.
5. It is then pumped to the end consumer’s house at a pressure of 4.3 bars.

Five storage tanks contain a total volume of 6000 cubic meters of water for emergency.

The entire plant is a self-sustaining process but is supervised from 7 am to 4 pm by the workers.

Aeration, pumping power, turbidity, power consumption, the pumps themselves, conductivity, pressure and pH are observable in the plant and on the internet after passing certain security measures. Changes in these values can indicate microbia-presence, which will then be followed by an investigation of the state department of health in its laboratories.

Aeration, pumping power, used power, the pumps and the pressure are even manageable (from all over the globe) over the internet, digital interfaces and manually (manual is prioritized to avoid hacking).

If hygienic errors are detected, the state department of health steps in (solution or quarantine). Chlorine is always ready for use but up to know has never been used in the history of the plant due to no respective bacteria being present in the water.

7.3.2 Description of the processes and methods in the water abstraction and purification plant in Serampore

The water treatment plant at Serampore produces 90 million litres/90 thousand m^3 of water per day bearing the responsibility of supplying portable water to 7 towns of the region.

The aims of the plant are:

1. **Reducing turbidity** of water to less than 1 NTU (Nephelometric Turbidity Unit).
2. **Destroying all microbes** and harmful chemicals in the water. It uses several processes like the aims 4 to 7.
3. **Abstraction** - The process of drawing water from the river.
4. **Pre-Chlorination** - Addition of chlorine to kill germs.
5. **Foam Formulation** - Separation of slag from the water.
6. **Clariflocculation** - The process of colloidal sedimentation.
7. **Filtration** - Removal of impurities using sand, grains and gravel.
8. **Storage** - Storage and distribution of purified water.

There are two laboratories that test the water for bacterial and chemical contamination. Further details are discussed in chapter 6.

The large amount of water that is purified per day employing large amounts of machine and labour, making it very cost intensive (Basu, 2015b).

7.3.3 Comparison of both water abstraction and purification plants and deduction of the relative effort

7.3.3.1 Effort measured by time and output

Firstly, we'll focus on the amount of water made available for consumption. We'll compare the amount of water made available in total and per resident of the respective city.

The maximum output of the "Wasserwerk EWE" in Cuxhaven is 625 m^3/h that is 15,000 m^3/d. The average output of the abstraction and purification plant in Serampore is 3750 m^3/h that is 90,000 m^3/d. For that one has to keep in mind that Kolkata has 14,755,186 inhabitants to be provided with water (World Population Review, 2019) whilst Cuxhaven only has to provide water to 48,221 inhabitants (Statistisches Bundesamt, 2014). The total effort is hence automatically way higher for Kolkata's abstraction and purification system.

Before going into further detail of process comparison, it makes sense to calculate the efficiency of the effort productivity-wise. This determines the effort to grow the quantity of citizen's support with clean water. In Cuxhaven, one citizen is provided with a rough average of 0.311 m^3 or 311 l of processed water a day. On the other hand, Kolkata's citizens have an average quantity of 0.006 m^3 or 60 l of water at their disposal, which only counts city inhabitants being supported and excludes villagers from outside the city from the equation. The relative effort to provide citizens with water in Cuxhaven is hence almost 5 times higher than in Kolkata due to differences in population size.

7.3.3.2.1 Effort measured by number of processes, machines and their expenses

The water abstraction and purification plant in Kolkata uses 8 different steps in ensuring the water's quality. In Cuxhaven, the Wasserwerks' water only undergoes 4 procedures before being pumped out to the consumer. Even if excluding the 6 times higher output per day of the plant in Serampore, it is safe to say that the expenses of maintaining twice as much machines is the reason for higher expenses for maintaining and working the machines. Power costs, loans and repair costs should automatically increase with the number of processes and machines used.

7.3.3.2.2 Reasons for expense differences in water purification and abstraction

The main reasons for expense differences in water purification efforts can be explained by looking at the kind of water that is purified. Kolkata mainly uses surface water from the Ganges and its distributary, the river Hooghly, as a source for water. In contrast to that, Cuxhaven's water source is 100 % ground water.

Ground water is protected from most contamination because the water has to run through several layers of different soil and sand before it reaches ground water level. If the soil and sand are not contaminated in some way, some contents such as minerals, metals and biotic matter are already filtered out when the water reaches the "Wasserwerk".

Fig. 7.2: Pollution of a channel supporting the East Kolkata Wetlands (photo: Breuer, 2019)

On the contrary, the Ganges is one of the most polluted rivers in the world, being used for hygiene, washing, getting rid of rubbish, industrial waste and dead bodies *etc.* by the native population (Wakefield, 2019). We ourselves could observe some of that pollution when we visited the wetlands (Fig. 7.2).

If we then consider that the sub-tropic climate of the area has ideal temperature for bacterial and algae growth, water remediation has to be a larger effort.

To reduce the effort to a minimum, the location for the water plant in Serampore was carefully chosen to be one of the river's least contaminated ones.

7.3.3.3 Efficiency of the processes undergone/value of the efforts measured by water purity

As a part of our exchange program, another student group prepared a scientific report by measuring different types of water bodies from both Kolkata and Cuxhaven and comparing them (see chapter 8).

By contrast, this report is only concerned with the quality of the tap water because that's the water that has undergone water treatment. The only real difference between Cuxhaven's and Kolkata's tap water seems to be a slightly higher arsenic content in Kolkata's due to the river Ganges rising in the Himalayas mountains (see chapter 4).

Statistically, the sample size of our projects' analyses was small, ranging around ten samples in total. Each sample was taken from a different location, so the sample size for each location was actually one, way too small to be significant. However, the samples could at least be counted as indicative of a problematic situation.

Regardless, the higher arsenic content in Kolkata's tap water most probably isn't the result of lesser effort applied by the Serampore water treatment plant. Compared to every other body of water, the Ganges'/Hooghly's water sample exceeded all other samples' arsenic content by far. Hence, the slight amount of arsenic left in the tap water is an achievement of an even higher effort in Serampore because Cuxhaven's water treatment plant isn't met with such circumstances for water remediation.

Other differences in water quality would include more chlorine being present in Kolkata's tap water. Low chlorine concentration in the water isn't harmful to humans whilst killing off germs. However, the chlorine impairs the taste. Again, the Ganges' organic pollution is at fault. Bacteria and other biological matter have to be treated with chlorine. This doesn't have to be done in Cuxhaven because there's never been a presence of something that had to be treated that way in the groundwater according to Cuxhaven's treatment facility's director Frank Schmitt.

7.3.3.4 Differences in used land mass

A comparison of the landmass used would not make much sense because the types of water used are different. The water treatment plant in Serampore gets its water

from a rather fast flowing body of surface water, whereas the Wasserwerk in Cuxhaven pumps out slowly flowing ground water from a 3000 hectare large region.

7.3.4 Comparison of both sewage treatment sites and deduction of the relative effort

7.3.4.1 Description of the sewage plant "Klärwerk EWE" in Cuxhaven as well as its processes and methods of water remediation

The information in this chapter is taken from the website of the Klärwerk EWE in Cuxhaven (EWE Wasser GmbH, n.d.) as well as pers. com. of Karsten Rathjens, who guided us through the plant.

The sewage treatment plant, located in the Neufelder street in Groden, Cuxhaven, is the main control centre for treating wastewater throughout the year. From 1999 to 2001, most of the operations were controlled manually but now the working hours are limited from 7 am to 4 pm as the rest of the controlling can be done online.

The plant consists of two big pipes having a diameter of 1 metre each which receives 2500 cubic meters of sewage water per hour from the households, specific companies and the industries. There are also some specific companies, which bring their sewage directly to the sewage treatment plant and not through the canals. The plant produces 13,000 m^3 per day.

7.3.4.1.1 Mechanical cleaning procedure:

The first part of the purification process works mechanically to get rid of solid impurities and it comprises two steps:

First Step:

From the unfiltered water, the large and solid waste materials are taken out first which looks like a big sink like grill (1 cm gaps) which acts as a sieve takes out the material wastes like food items, tissue papers, etc. This process is carried out in a closed tank because it smells a lot because this wastewater contains dissolved methane gas.

Second Step:

Sand, glass and stones are removed from the water in this step. The grill like sieve used in the first step cannot be used here because it the solids will pass through 1 cm gaps. Thus, the water is made turning to use the gravity to separate the different particles. The cone shape achieved by spinning the water makes the travelled way of the water as long as possible, which allows for better cleaning.

7.3.4.1.2 Chemical cleaning procedure

The mechanical treatment is followed by chemical treatment, comprising the purification steps three and four.

Third Step:

Wastewater from the industries and households was separated and the water at this point mostly contains fats and proteins. Microorganisms are cleaning up the water using aerobic and anaerobic chemical processes. The most important process they are involved in is nitrification. Nitrification is regulated by oxygen input: If there's more ammonium present, the oxygen level is increased, if ammonium is low, it's decreased. This manages the nitrifying processes the bacteria participate in. Every substance level is maintained by oxygen and a nitrate probe. The maximum value of ammonium is 10 mg/l, and the maximum value of all nitrogen-types is around 18 mg. The value should however be far lower than that. At that the moment, it was around 3 mg/l. The level of oxygen is controlled by aerators, which need 60 % of the whole electricity consumption (1350 kW) of the plant. In addition to the nitrification, the cell respiration of the bacteria decomposes present carbon (carbon dioxide).

Fourth Step:

The microbes are separated from the clear water and after the process of centrifugation and sedimentation; the clear water is let out into the North Sea. The separated microbes are partially directed into a cultivation centre called "Belebungsbecken" (activated sludge tank) where they're cultivated for later use. The bacteria fortunately fall out in flake-like groups with carbon bonds. However, the resulting water is not fit for drinking. Leftover mud is compressed and mixed with a kind of glue (polymer and electric charge) so it sticks together. This mud makes up 30 % of the water mass and 8 containers of it are filtered out every day.

7.3.4.1.4 Final steps

The laboratories of the plant test the clear water for phosphate, ammonia and the presence of other chemicals as it is mandatory to have the correct values. However, small changes in composition of water due to oil or medication can't be recognized because the huge amount of water mixed has a strong dilution effect.

The water from the slum is used by the famers as fertilizers but this is going to be forbidden in some years. It will then be sent to the power plants for burning purposes. Most of the leftovers of the cleaning process are already getting burned. The ashes then contain phosphate, which can be recovered.

The so called "Faultürme" or "rotting towers" are two 5500 m^3 big towers in which some leftovers - such as the superset of bacteria not needed for the processes – are pumped. Then, the bacteria and the decaying waste together lead to mostly methane and some carbon dioxide emissions. The produced methane is used to power the facility. In winter, the heating system solely relies on this process.

7.3.4.2 Description of the East Kolkata Wetlands as well as their processes and methods for water remediation

To reduce repetition, we are going to quote the most important concluding points of chapter 6. Also, for the rest of this report we are going to use the abbreviation "EKW" for the East Kolkata Wetlands.

Our conclusive description about the ecosystem and the effort to use it went as follows: "The wastewater is led into the 12500 hectares large EKW through a channel system and there it is purified in established, commercial fish ponds and garbage farms as well as by the already present flora. Hence, not only does there need to be several pumping and purification stations as well as channels, but also a large ecosystem has to be maintained. […] This effort, which at first seems quite huge, is minimized by several circumstances. Not only is the water efficiently cleaned in respect to heavy metal and algae pollution even before it has to be pumped out of water by a specific plant, saving time and effort. Also, the processes used in the EKW water remediation efforts are either naturally present (e.g. the *Eichhornia crassipes*, which clean the water and stabilise the *bheris'* walls) or self-sufficient (fish-*E.coli*-cycle).” (see chapter 6).

Furthermore, regarding the circumstances of sewage remediation, our research concluded, that “[m]ost of the pollution that's dealt with in the EKW are different types of industrially used heavy metals like copper, lead, zinc and cadmium as well as chrome. Bio-pollution is limited to various algae and *E. coli* bacteria. […]” (chapter 6)

In the end, concerning the procedures the sewage water undergoes, our report concluded the following: “The most important procedures of water remediation in the EKW are rhizofiltration and the fish's feeding on algae. Rhizofiltration is largely based around the *Eichhornia crassipes*, which bind heavy metals, grease and oils in their roots whilst maintaining nutrition from the ground they're standing on. […] In the end, some of the polluting content in wastewater as well as garbage will be used to irrigate and fertilise paddy fields.” (chapter 6).

Furthermore, certain bacteria present in the water lower the ammonium content of the water by a process called nitrification, which makes it non-toxic. More about that can be found in the report “Analysis of water samples from Cuxhaven, Germany and Kolkata, India” (chapter 8).

7.3.5 Comparison of both sewage treatment sites and deduction of the relative effort

7.3.5.1 Effort measured by time and output

The EKW put out a purified water mass of 750,000 m^3 per day, which is a third of Kolkatas wastewater (The Hindu, 2016). The sewage plant “Klärwerk EWE” in Cuxhaven only puts out 13,000 m^3 per day.

From this, we can deduce the amount of remediated water the inhabitants of each city might “produce” daily manageable by the two treatment sites. For the EKW, we come up with a number of 0.05 m^3 or 50 litres of remediated water per day for each of the 14,755,186 inhabitants (World Population Review, 2019). For the “Klärwerk EWE”, we concluded that 0.27 m^3 or 270 litres are remediated each day per citizen of Cuxhaven (which comprises 48,221 inhabitants (Statistisches Bundesamt, 2014).

Again, because it has to deal with a larger population, the absolute effort in the EKW is automatically higher than the one applied in the “Klärwerk EWE”. However, the effort per citizen measured by output per citizen is once again 5-6 times as high in Cuxhaven compared to Kolkata.

7.3.5.2 Effort measured by number of processes, machines and their expenses & reasons

This comparison falls short because the systems used are fundamentally different from each other. The EKW are an ecosystem with 264 commercial fish ponds (Ghosh, 1999) as well as garbage farms spread over a surface area of 12,500 hectares. This entire site is then connected by a net of several pumping stations and pipelines getting the water from Kolkata’s sewage and the Ganges into the fishponds, mostly so called *bheris*.

The economic expense is kept relatively low by using already present natural circumstances and private farming companies. Firstly, already present *Eichhornia crassipes* are used for rhizofiltration which are extremely successful at getting heavy metals, grease and oils out of the water. Secondly, fish kept in the water clean it of algae and get fed by it. Thirdly, fertilizers out of waste are used to irrigate fields with all kinds of food. And, at last, naturally occurring bacteria are used for nitrification.

The private entrepreneurs maintaining the fields and fishponds ensure no resources going to be wasted and also produce valuable food, whilst the natural circumstances such as plants and algae almost self-sufficiently maintain the remediation process. This presumably keeps the net gain higher than in the “Klärwerk EWE”, because the companies that are active in the EKW might also carry some expenses on their own without taking money from taxpayers.

The “Klärwerk EWE” in Cuxhaven on the other hand uses pumping mechanisms and a four-step cleaning process involving roughly 4 machines. This is more steps than the EKW uses, but the cleaning is also more thorough than what’s done there.

Furthermore, there are fewer natural circumstances used than in the EKW, which automatically means higher expenses. To name the most prominent two, the “Klärwerk EWE” farms bacteria out of the sewage water which it then uses to effectively clean it by nitrifying processes. Secondly, gases produced by the waste in the sewage water are used to power the facility partially in winter.

The effort of expense, number of processes and number of machines used is hard to deduce, but obviously the effort applied in Cuxhaven is higher than in the EKW.

Reasons for this are the natural circumstances in Kolkata, which are a much better fit for water remediation than those in Cuxhaven, where an artificial facility had to be installed. However, the EKW are also only responsible for a third of the city's sewage whilst the "Klärwerk EWE" is responsible for all of Cuxhaven's sewage.

7.3.5.3 Efficiency of the processes undergone/value of the efforts measured by water purity

The other study group's samples did also include samples from the East Kolkata Wetlands as well as samples from the river Elbe (chapter 8).

The river Elbe is where the purified water from the "Klärwerk EWE" is led into, however, it is a long river crossing many European regions. Hence, this sample is of close to no value for this comparison. However, the federal department of health regularly checks the water produced by the plant for contaminations under the threat of closing the plant down. The "Klärwerk EWE" also conducts tests in its own laboratory. Thus, it's safe to assume that the water is clean from really toxic contents. As the groundwater has to be freed of iron and manganese, one could speculate how much of those metals could still be present in the water. The water from the river Elbe is high in e. g. iron content (chapter 8), which could indicate that this isn't successfully cleaned out of the sewage or wastewater in the "Klärwerk EWE". But, as already stated, any such process would be unnecessary anyway.

What can moreover be said is that the water from the EKW has no special properties except for a high nitrate value. This is a positive sign showing that the toxic ammonium lowering process in the water by nitrifying bacteria is taking place well (chapter 8).

Both sewage treatment sites produce nitrified water by using inherently prokaryotic bacteria. They would not be well equipped for cleaning medication such as antibiotics, which are harmful against such bacteria (Williams, 2011). In fact, high amounts of these medications could impair or even destroy the nitrifying process, making the water toxic. Hence, rigorous testing of the water is necessary to ensure no such thing happening. This quality control is happening better in Germany, as a

control mechanism is installed inside the treatment plant to ensure all standards being met.

7.3.5.4 Differences in land mass used

As already stated, the EKW in Kolkata use a landmass 12,500 hectares large. The "Klärwerk EWE" in Cuxhaven occupies a rough approximation of 2.3 hectares. This seems far more effectively, to be precise, 5,435 times more. However, the sewage treatment plant in Cuxhaven does neither produce fish nor vegetables. Neither is it home to hundreds of species or home of 264 companies (Ghosh, 1999).

The large amount of landmass used by the EKW sewage treatment are cause of controversy in Kolkata, as it has a growing population that needs buildings to live in.

In the end, the two sites are also close to incomparable in this category, because the EKW are very multifunctional whilst the "Klärwerk" only serves one distinct function.

7.4 Conclusion

To answer the questions posed at the beginning of this report, the city of Cuxhaven, Germany invests a high and successful effort per inhabitant into abstracting and purifying both sewage water and tab / drinking water. The volume of water produced is enough to deal with emergencies and enables widespread use, which is good for hygiene and overall quality of life in this region.

This evens out with the overall effort applied in Kolkata, India. Cuxhaven provides each inhabitant with an average of 311 litres of very clean water whilst the water abstraction plant in Serampore / Kolkata provides roughly 300 times as many people with less volumes and works together with several other plants to do so. Other differing circumstances between the cities are that Cuxhaven mainly uses largely decontaminated ground water as a drinking water source whereas Kolkata must deal with highly polluted surface water from the river Ganges / Hooghly for the same purpose. On the other hand, Kolkata has a 12,500 hectares large ecosystem called East Kolkata Wetlands, whose natural circumstances allow for widespread and thorough sewage treatment as well as agriculture without much artificial altering. This, combined with most of the sewage treating ponds being privately owned, appears very cost efficient, but requires a lot of surface area. The "Klärwerk EWE" in

Cuxhaven requires way less space and does the job of water treatment equally as well. However, it is less multifunctional than the East Kolkata Wetlands, which are a cultural good, a valuable ecosystem, a home and workplace for hundreds of families and a sewage treatment site combined.

Kolkata and Cuxhaven both use processes of nitrification by bacteria to clean their sewage water from ammonium. Both cities use pumping stations to abstract the water.

Kolkata mainly abstracts water from the river Ganges, whilst Cuxhaven abstracts groundwater by wells. In Cuxhaven, most contents have already been filtered out by different layers of soil. Only iron, CO_2 and manganese must be taken out by aeration to deacidify the water. The treatment plant in Serampore must use different sands and sedimentary processes to filter out polluting contents such as minerals. Also, the water has to be chlorinated because the harmful biological and bacterial content in the rivers' water is very high.

The sewage treatments differ in many ways: Cuxhaven uses a treatment plant that applies machinery such as a sieving machine, an aeration machine and a mud processing machine to the water to keep it clean. Kolkata uses the EKW for a third of its sewage, which are a natural ecosystem. The main processes used besides nitrification are fish eating algae out of the water and water hyacinths doing rhizofiltration against heavy metals, grease and oil. These are not completely naturally present, but self-sufficient.

The usage of Ganges water results in Kolkatas tap water being slightly more arsenic than Cuxhaven's tap water. Other differences in water quality are discussed in the report of chapter 8 in detail.

8 Analysis of water samples from Cuxhaven, Germany and Kolkata, India

8.1 Abstract

"Is the water we drink safe for us" is the main topic of the present report. Therefore, we took water samples from many different sites in Germany and India, more precisely in Germany are water from the Elbe at the estuary of Cuxhaven, a private duck pond, a tide creek in the Wadden Sea, an agriculture ditch, the Marina Cuxhaven, as well as filtered wastewater, industrial water feed, communal water feed from the purification plant and water from the abstraction plant of Cuxhaven. The samples from India were tap water from the schools SBGS and BHS, the Ganges / Hoogly, purified water from the wetlands (EKWs) and from a Kolkata pump station (distributed all over the city to supply homeless people). All these samples were tested on the minerals of ammonium, nitrite, nitrate, phosphate, arsenic, copper and iron. Additionally, some samples were analysed for arsenic and lead by a commercial laboratory (Labor IBEN, Bremerhaven, Germany).

The basic insight we got was that the drinking water in Germany and India is safe to drink, but Germanys' water is a little superior. Especially the arsenic concentration on average is lower in Germany than in India, but for example every water sample (except the duck pond, probably because of the timing the water sample was taken) contained the same amount of phosphate and ammonium.

In comparison to the previous year measurements (i.e. 2018) nothing had changed in a significant extend, everything was still healthy. However, we are looking forward to compare the measurements of the next years (2020 onwards) to the already existing data to extract new information about the water qualities in India / Kolkata and Germany / Cuxhaven.

8.2 Introduction

We drink water every day but the question is, "is the water we drink safe?" This is what our report studies, taking water samples from various sources all over Kolkata and Cuxhaven and their surroundings. So first, where does the water we drink come from?

In Kolkata, the Hooghly River, a distributary of the river Ganges, is the main source of potable surface water for the city of Kolkata supplied from the age old Palta Water Works now rechristened as the Indira Gandhi Water Treatment Plant. Meanwhile water in Cuxhaven is mainly obtained from groundwater which is purified at the abstraction plant “Wasserwerk EWE” Cuxhaven.

We visited the Serampore Water Treatment Plant, Kolkata and the “Wasserwerk EWE” Cuxhaven to collect water samples for our study. Other samples were collected from the East Kolkata Wetlands, the River Ganges and from the taps of Sushila Birla Girls´ School as well as of Birla High School in Kolkata. Samples were also collected from various water bodies in or near Cuxhaven, a private duck pond, an agricultural ditch, the Marina Cuxhaven, a tide creek in the Wadden Sea and the River Elbe.

All the samples were tested for ammonium, nitrite, nitrate, phosphate, copper and iron content, as well as the turbidity in the laboratory at Amandus Abendroth Gymnasium in Cuxhaven. This was determined using sera aqua test box according to the instructions given in the users´ manual. The respective experimental instructions for each parameter were strictly adhered to.

Other parameters such as lead and arsenic content were measured at IBEN laboratory, Bremerhaven. While some of these elements are essential at low levels they act as pollutants and may prove to be toxic in higher concentrations. In the given study we have detailed our findings from the analysis of these water samples. These findings have been compared to previous findings from a similar analysis in the years 2016 and 2017 that were conducted by former student exchange projects.

Our project also took into account the importance of the Himalaya Mountains for the water of the Ganges and the river Hooghly.

A further comparison is drawn between samples of Cuxhaven and those of Kolkata. The results have then been visualized through diagrams and graphs.

An important factor here is the nitrogen cycle. The nitrogen cycle represents the circulation of the element nitrogen in various chemical forms through nature. Nitrogen is a component of proteins and nucleic acids. It is, thus, essential for life on earth. 78 per cent of the atmosphere is composed of nitrogen gas being a chemical form unusable by most organisms. Through a series of microbial transformations nitrogen

is made available to plants, which in turn ultimately make it available to all animal life. The steps are: nitrogen fixation, nitrogen assimilation, ammonification, nitrification, and denitrification (Fig. 8.1).

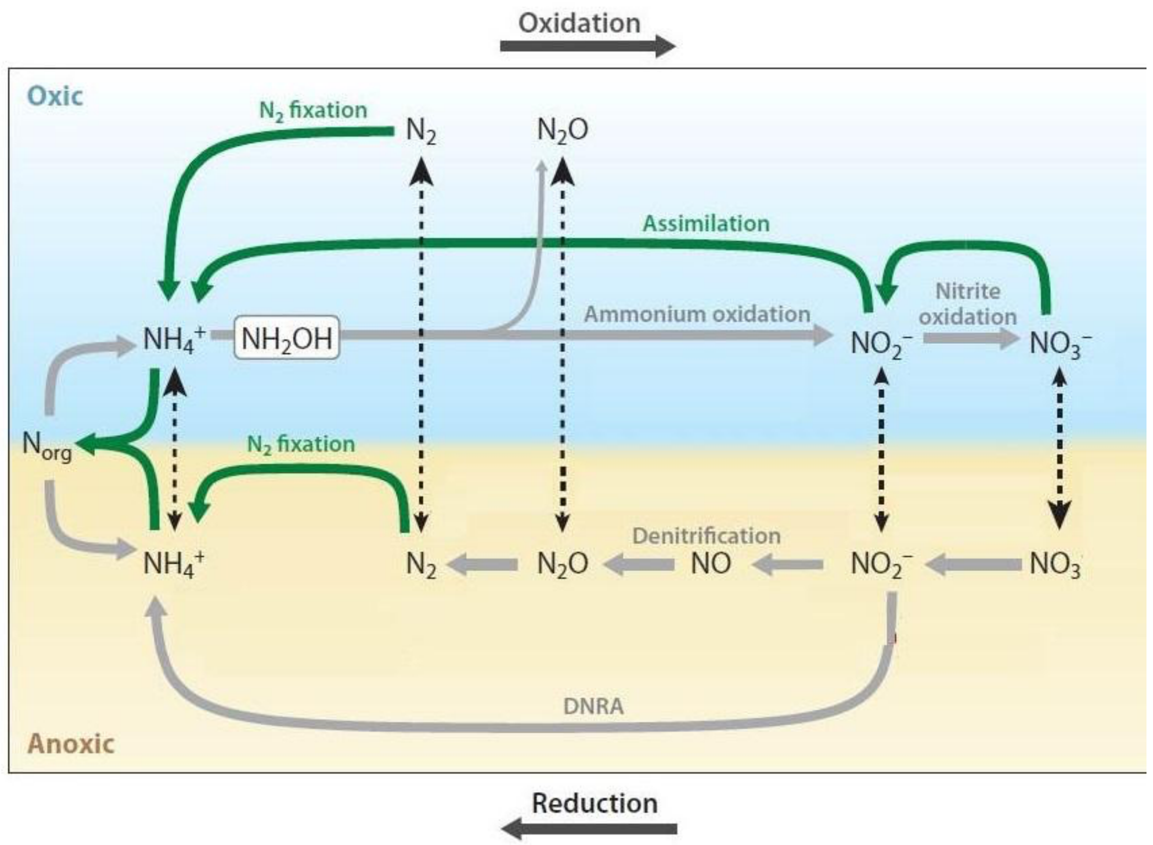


Fig. 8.1: Nitrogen cycle (GeogBlog at Trinity College, n.d.)

We have tested samples for traces of nitrates and nitrites which helped us develop an understanding of the processes of the nitrogen cycle and the various forms in which nitrogen may be found in the examined water bodies.

8.3 Materials and Methods

We used a number of materials and methods to analyse the various water samples and test them for the listed elements.

The content of ammonium was determined using the Sera aqua test box according to the instructions given in the users’ manual. Similarly, the Sera aqua test box was used to determine the contents of nitrite, nitrate, phosphate, copper and iron. This method is based on tests that use dyes, that is, the extent of the developing colour to show the content of the respective substances that is to be determined.

The samples from the sites in or near Kolkata were transferred to Germany, thus, could not be analysed directly after taking them. However, in order to minimise chemical reactions changing the original values samples were kept cold and dark whenever possible during the transport and storage.

German samples were taken the day before analysis.

8.4 Results and discussion

8.4.1 Mineral present in samples (set 1)

Minerals such as nitrate and phosphate represent nutrients for the growth of plants. Thus, they are used as fertilisers for farming where they might enter the ground water and / or can be washed out by rain falls and enter agricultures ditches and from there flow into larger currents and rivers. Although being essential for the growth of plants, at high concentration they lead to eutrophication of water bodies and, ultimately, to ecological disturbances of the balance of the system (Williams, 2011). This, these minerals provide significant information on water qualities.

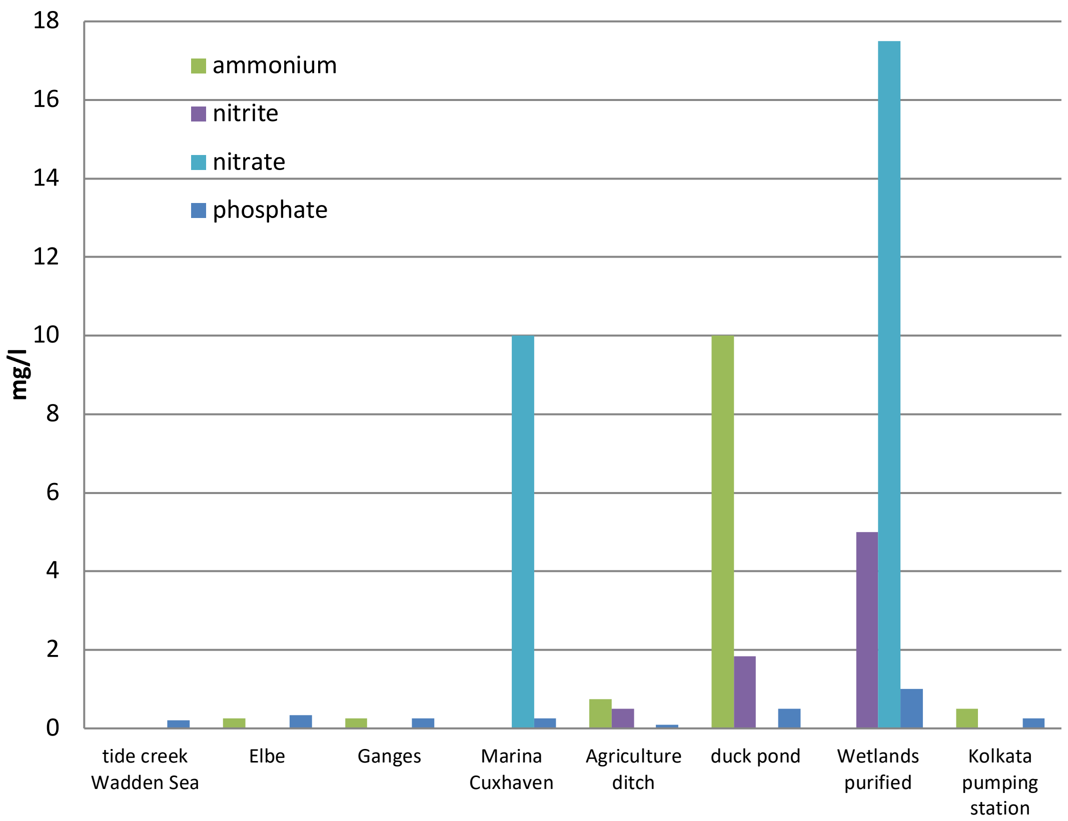


Fig. 8.2 A

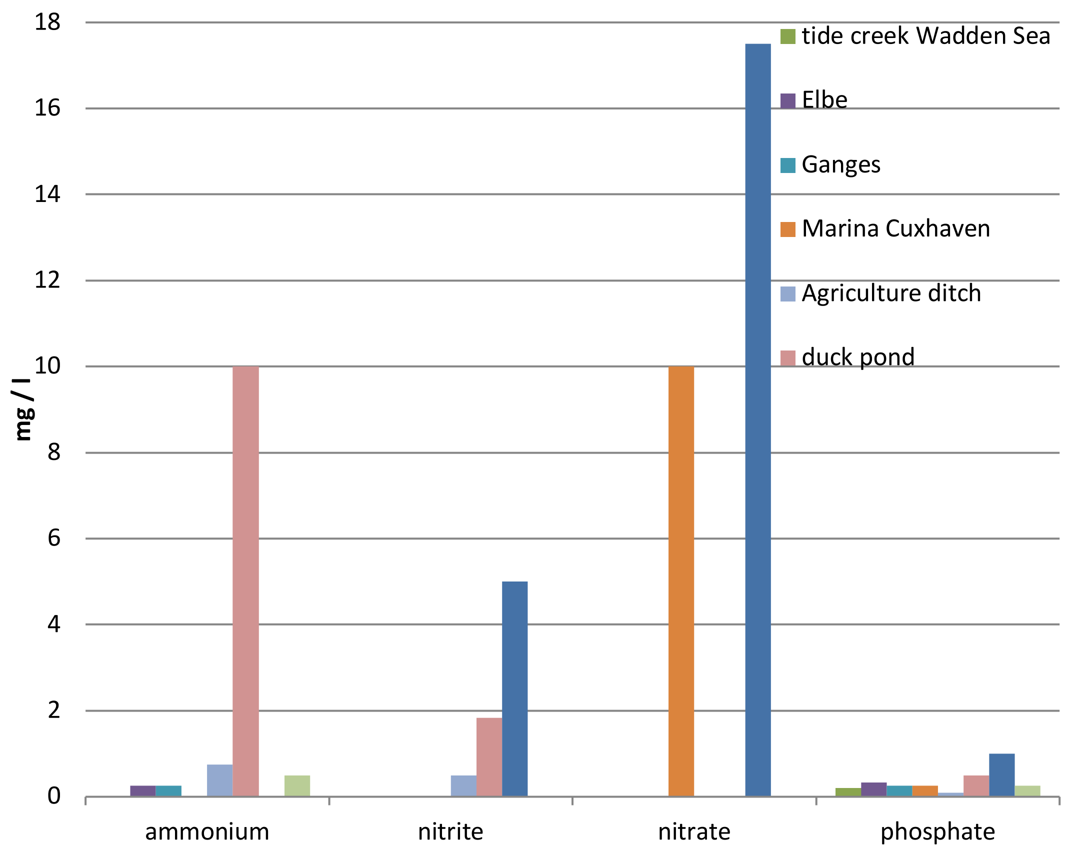


Fig. 8.2 B

Fig. 8.2 contents of minerals detected in water samples set 1, A sorted by the sampling point, B, sorted by the type of mineral

The bar chart Fig. 8.2 A and B shows the amount of four different minerals which are ammonium, nitrite, nitrate and phosphate present in samples taken at seven sampling sites: a tide creek of the Wadden Sea, the Elbe, the Ganges / Hooghly, the Marina Cuxhaven, an agriculture ditch near Cuxhaven, a private duck pond in Germany, the purified water of the East Kolkata Wetlands and a pumping station in Kolkata. The samples were taken and analysed in May 2019 using the sera aqua test box.

Ammonium was mostly present in the duck pond. The amount reaches 10 mg/l. The lowest ammonium concentration of 0 mg/l was found in the Wadden Sea tide creek, the Marina Cuxhaven and the purified wetlands water. For the other sampling sites ammonium was present but in a very low amount.

Nitrite was present in 3 out of 8 sampling sites. The purified wetlands water had the highest nitrite amount of around 5 mg/l. The agricultural ditch and the duck pond also contained a small amount of nitrite being 1.83 mg/l for the duck pond and 0.5 mg/l for the ditch.

There are only a few samples where nitrate was found in: Firstly, the Marina Cuxhaven with 10 mg/l and secondly, the purified wetlands water with 17.5 mg/l.

All sampling sites contained phosphate. The lowest amount was present in the ditch, roughly 0.1 mg/l and the highest amount was 1 mg/l in the wetlands. The other samples just showed a small amount of phosphate.

Since ammonium (NH_4^+) is a product of decomposition of proteins like faeces or organic waste by bacteria, the amount is really high in the duck pond. Bacteria decompose the ducks' faeces and transform them into ammonium. Ammonium is also introduced into the water by fertilisers that are added in agricultural processes. Thus, the agriculture ditch shows a small amount of ammonium. Both rivers have a small amount of ammonium, because of the ammonium content of entering smaller currents but also because the fish produce it instead of urine that would be produced by birds or mammals. Also, the fish release faeces as waste after feeding on algae or smaller animals. Bacteria decompose these waste products and transform them into ammonium. A low concentration (0.5 mg/l) of ammonium is already toxic for fish, but not for humans (Gerber *et al.*, n.d.).

Nitrite (NO_2^-) is an intermediate product of the nitrification process (Fig. 8.1). Ammonium only gets converted into nitrite when enough oxygen is available to start the chemical reaction. Also, further conversion into nitrate can only occur when sufficient oxygen is available. This mineral is highly toxic for living organisms because it reacts to amino acids and generates carcinogenic nitrosamines (Lethen, n.d.).

The reason for the rather high amount of nitrite in the wetlands has to be the amount of oxygen in the water, which depends on the balance between the photosynthesis of plants / algae and the cell respiration of all consumers, mainly the bacteria and fish. This oxygen is needed for nitrification to take place. A lack of oxygen in the water means that there isn't enough to convert all ammonium into nitrite as well as not enough to keep the whole amount of nitrate from reacting back to nitrite (Lethen, n.d.). Another reason for the amount of nitrite in the water is the time the water sample was taken. Possibly, the whole nitrite had not enough time to be converted

completely to nitrate by the bacteria since the time point the wastewater was led in the sampled basin. The duck pond water sample was taken one day after refilling the pond. Thus, the whole ammonium amount due to the ducts activities probably did not have the time to be converted into nitrite, respectively nitrite to nitrate.

The small amount of nitrite which was present in the agriculture ditch can be explained by the fact that the ditch has not been dunged for a longer time. Usually, farmers apply the fertilisers during spring time to their fields. *i.e*. March, however, sampling was carried out in May. This means, at that time there is just a small amount of ammonium, which might get converted easily into nitrite and nitrate in the water.

In contrast to the former discussed water bodies the rivers are non-static water bodies meaning that there is a lot of water movement and, thus, oxygen intake in the water facilitating the nitrification process. Additionally, the rivers represent a high volume of water leading to an immense dilution effect. Thus, determined values (fig. 8.2 A and B) were generally low. However, this can be just an apparent lack of nitrogenous substances. This can be concluded from the values obtained from the Marina Cuxhaven where especially the nitrate content is rather high. The Marina also contains water originating from the river Elbe, but, despite being influenced by the tides, the dilution effect might be much smaller. There is no nitrite in the tide creek of the Wadden Sea as there was also no ammonium. This could mean that nitrification cannot take place. Also, nitrogenous compounds introduced into the Wadden Sea by the Elbe and smaller currents could be washed out into the North Sea during high tides. Our values might also indicate the general nutrient poverty of the ecosystem of the Wadden Sea (Nationalpark Wattemeer, 2011). Anyway, nutrient loads of the Elbe might not impair the Wadden Sea – at least not at low tide.

Nitrate (NO_3^-) is a nitrogenous ion that is made when nitrification takes place (Augustyn *et al.,* 2018). It is the least toxic substance of the substances we have discussed. 2 of our 8 water samples, i.e. the purified wetlands water and the Marina Cuxhaven water, had a detectable amount of nitrate, the other 5 samples had none either because there isn't enough oxygen to convert all ammonium and nitrite into nitrate, or because the water sample was freshly taken. Again, the waters, taken from non-static sampling sites, could be diluted causing a very low amount of nitrate. This is a valid reason, because the water from the marina is the same as in the Elbe, but it is most likely static and there was indeed a detectable amount of nitrate. The water body of the marina has always a depth of at least 1.6 metres and 3.5 metres at its peak. This means, that the water till 1.6 metres is barely changing, providing time for the nitrogenous substances to be converted to nitrate.

Phosphorous does not exist in pure form in the nature because the element is highly reactive. Organisms need this element to build up their genetic material (DNA, RNA) as well as their ATP, an energy rich molecule that fuels all endergonic metabolic processes (Wikipedia. org). Consequently, faeces also contain this element. Phosphorous can be used as phosphate (PO_4^{3-}) in fertilisers and can get, because of this and also via industrial sewage water, into several water sources. A small amount of phosphate is always present in natural waters (Lenntech, n.d.). That is why some phosphate is present in each of our water samples. However, the amount of phosphate is quite high in the wetlands. This might be due to the faeces of the cows which live in the wetlands. Their faeces contain a high amount of phosphate which gets into the water either by rain or the cows themselves. It would be interesting to test this assumption by analysing water samples from farm land of the Weser-Ems region that is used for feeding huge amounts of cows whereas and , thus might also be more influenced by faeces in contrast to the area of Cuxhaven that focuses on growing crops and, thus should be more influenced by fertilisers.

8.4.2 Presence of the heavy metals arsenic and lead in the samples (set 1)

Heavy metal such as arsenic or lead can appear highly toxic when present at a critical concentration as they bind permanently on protein, e.g. enzymes, change their tertiary structure and, thus, can impair any basic metabolic process in an organism. Six out of our ten water samples were tested on arsenic and lead, being the Ganges, the Elbe, the purified wetlands water, the water of the marina in Cuxhaven, the tide creek of the Wadden Sea, the water of the pumping station in Kolkata and two different water samples from two schools in Kolkata. All of them contained the heavy metals arsenic (As) as well as lead (Pb) as shown in Fig. 8.3.

The Ganges has a rather high amount of arsenic because the Ganges rises in the Himalayas. The Himalayas' range contains stones which are partly made of arsenic. Arsenic is naturally present in these stones. Arsenic is affected by several chemical

processes under the influence of weathering, oxygen and water. Because of depletion of the water the groundwater table decreased such that the air can expand to the clay stratum of the Himalaya. Under the influence of the air and its oxygen the arsenic is changed into soluble compounds and set free into the water. The arsenic contaminated water flows into all the rivers rising in the Himalaya mountains and the Ganges is part of it. This might explain why the water from the wetlands has a lower amount of arsenic than the water in the Ganges (Fig. 8.3).

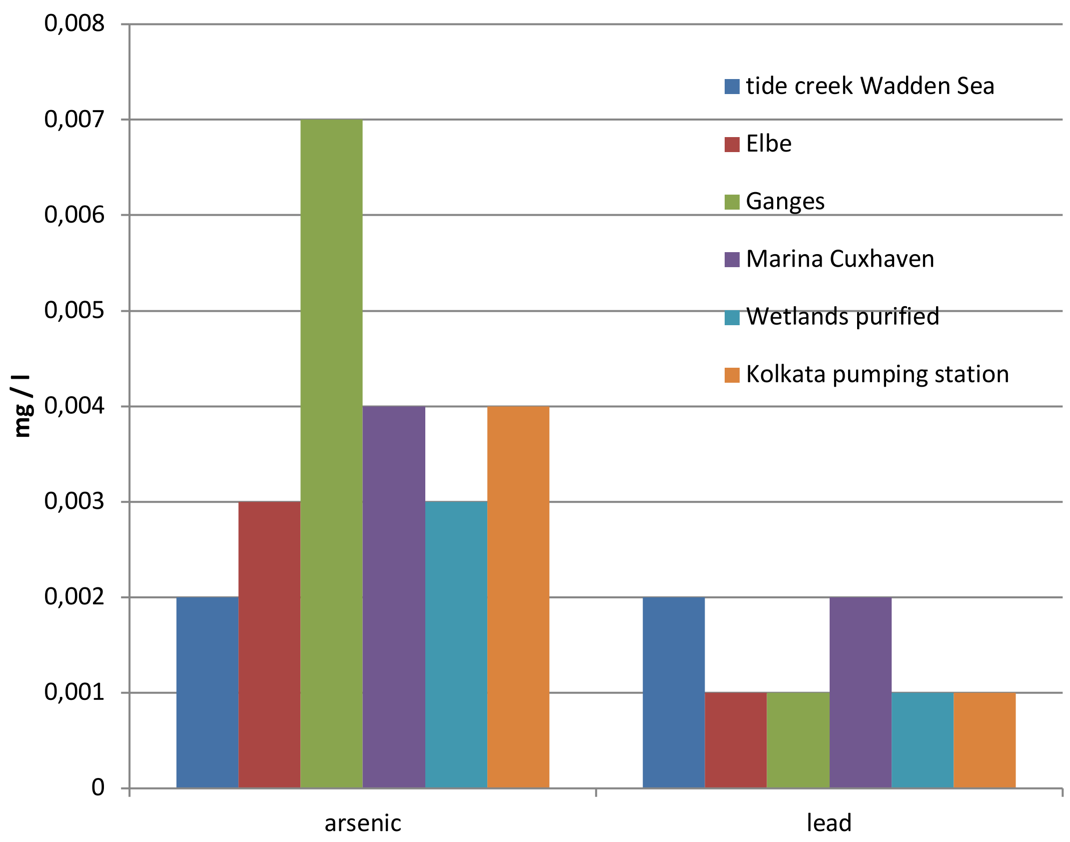


Fig. 8.3 Contents of arsenic and lead in water samples (set 1) analysed by Laboratory IBEN.

Arsenic is also present in the poorly filtered Ganges water in the households in Kolkata causing the low amount of arsenic in the wetlands, because the wastewater from these households feeds them. The water from the Ganges causes some arsenic content in the pumping station water, because the filtration does obviously not remove all arsenic (Fig. 8.3).

The arsenic found in all the other samples containing might be explained by the fact that some arsenic is always present in the ground water (WHO, 2011, Donner, n.d.).

As the amount of arsenic is dangerous when it is higher than 0.01 mg/l (Wikipedia.org. reference to WHO), all samples can be classified as uncritical.

In all of our tested water samples lead was present but just at small amounts: Four out of our six samples contained 0.001 mg/l, two out of them 0.002 mg/l. These were not dangerous because they were under the allowed critical limit which is 0.01 mg/l. Thus, the water from all testing sites was drinkable with respect to a possible heavy metal contamination.

8.4.3 Presence of iron and copper in the samples (set 1)

Seven of our ten samples were tested on iron (Fe) and copper (Cu) being the Elbe, the Ganges, the water of the marina in Cuxhaven, the purified wetlands water, Kolkata pumping station water and two samples that were taken in two schools in Kolkata (Fig. 8.4 and 8.5).

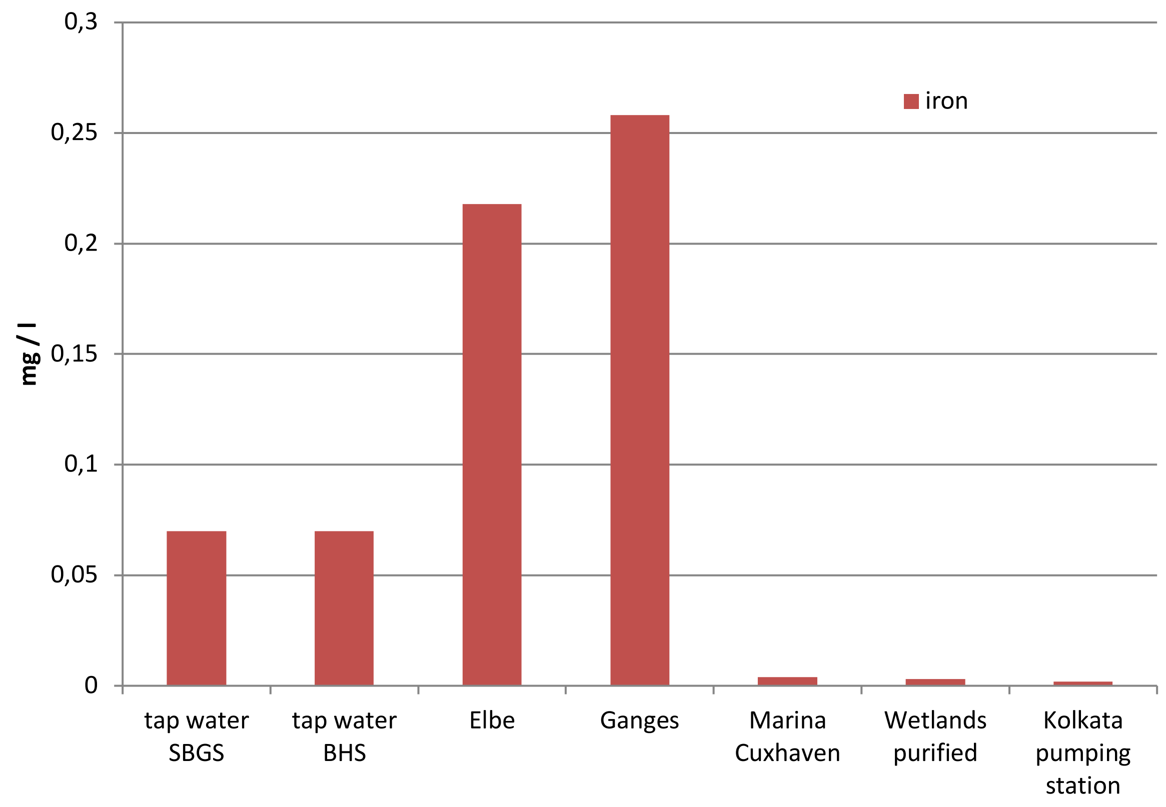


Fig. 8.4 Iron contents in water samples (set 1); SBGS = Sushila Birla Girls School, BHS = Birla Highschool

Six samples contained a small amount of copper. The only one with a noticeable amount of copper was the sample which was taken in one of the schools in Kolkata.

It has 0.02 mg/l. Maybe this amount in comparison to the other amounts is rather high, because the school could have used copper pipes. The second schools water contained no copper. We think that they use different pipes than the first school, pipes that are not made out of copper. All the others showed an amount below 0.005 mg/l. The allowed amount of copper in water is 2.0 mg/l (Wasserhelden, n.d.), so none of our tested samples even gets close to this limit (Fig. 8.5).

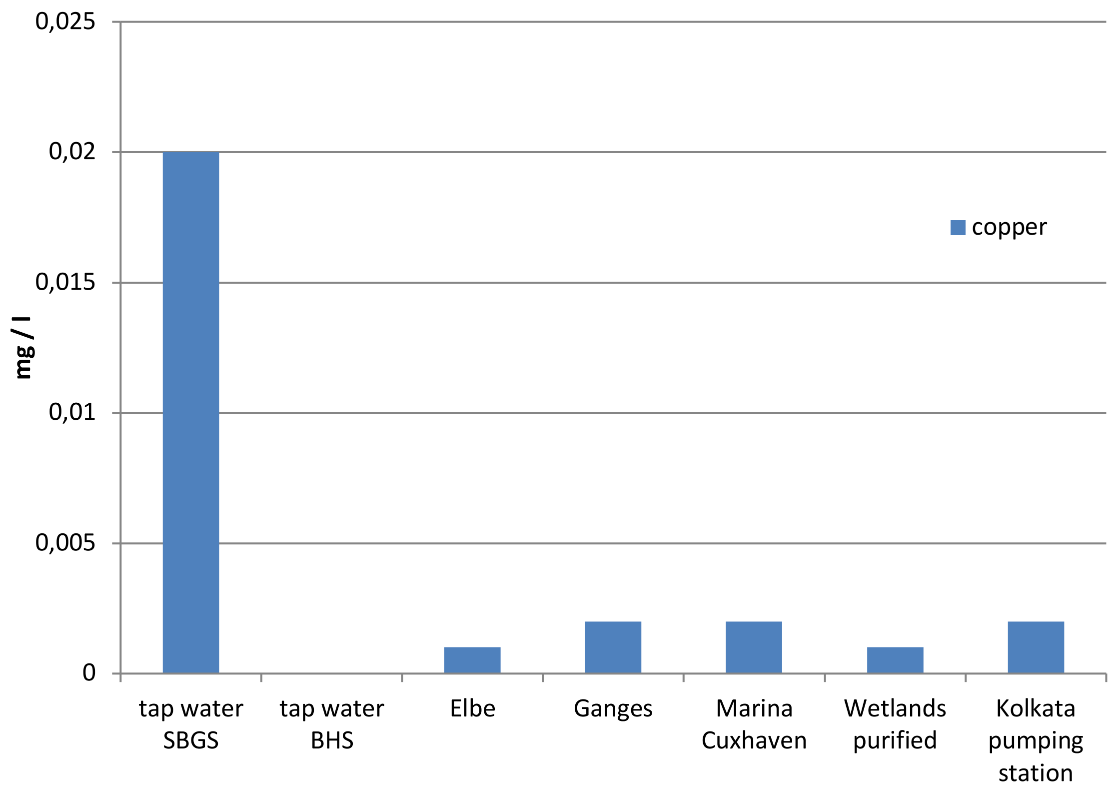


Fig. 8.5: Content of copper detected in water samples (set 1)

Iron is vital for the body. It is important because it is needed to bind the oxygen on haemoglobin within the red blood cells (Williams, 2011). A lack of iron in the body leads to a small amount of oxygen which is bad for the human body because sell respiration an, thus, the energy supply of the cells is reduced. If the amount of iron present in the body is too high it causes different illnesses (grossesblutbild.de, n.d.). Out of our seven water samples three did not contain a detectable amount of iron. The two tap water probes sampled from the schools in Kolkata, BHS and SBGS were below the limit of 0.2 mg/l (Bauer, 2019 with reference to Trinkwasserverordnung) and the two rivers Elbe and Ganges were above the allowed amount.

8.4.4 Presence of minerals in samples (set 2)

The bar chart fig. 8.6 shows the amount of four the minerals ammonium, nitrite, nitrate, phosphate as well as iron present in samples taken at three sampling points taken at the sewage water plant "Klärwerk EWE" Cuxhaven (filtered wastewater being completely treated, industrial water feed, communal water feed) and a water sample taken at a pumping well of the water abstraction plant (Wasserwerk EWE) Cuxhaven (taken before the treatment within the plant).

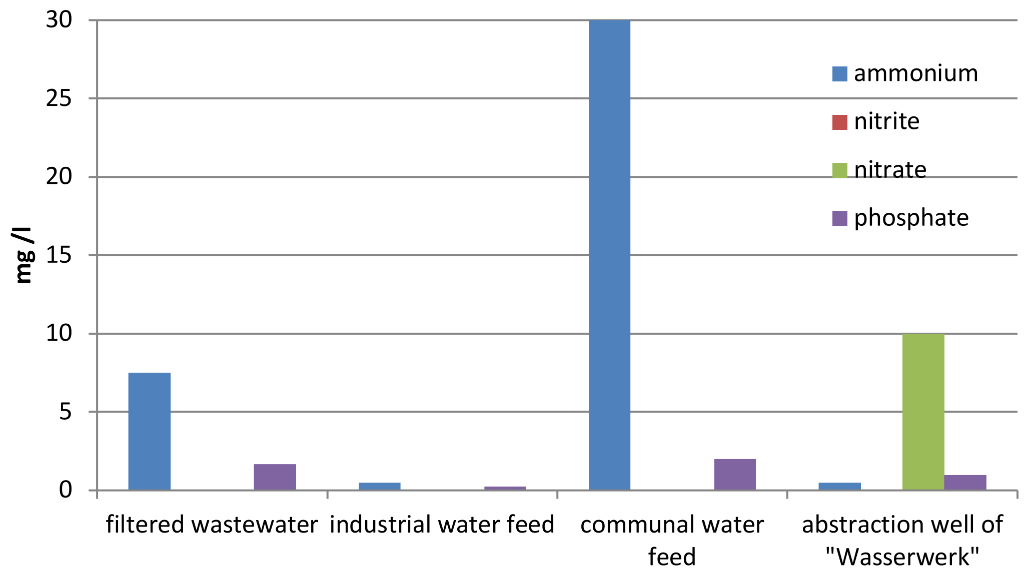


Fig. 8.6 A

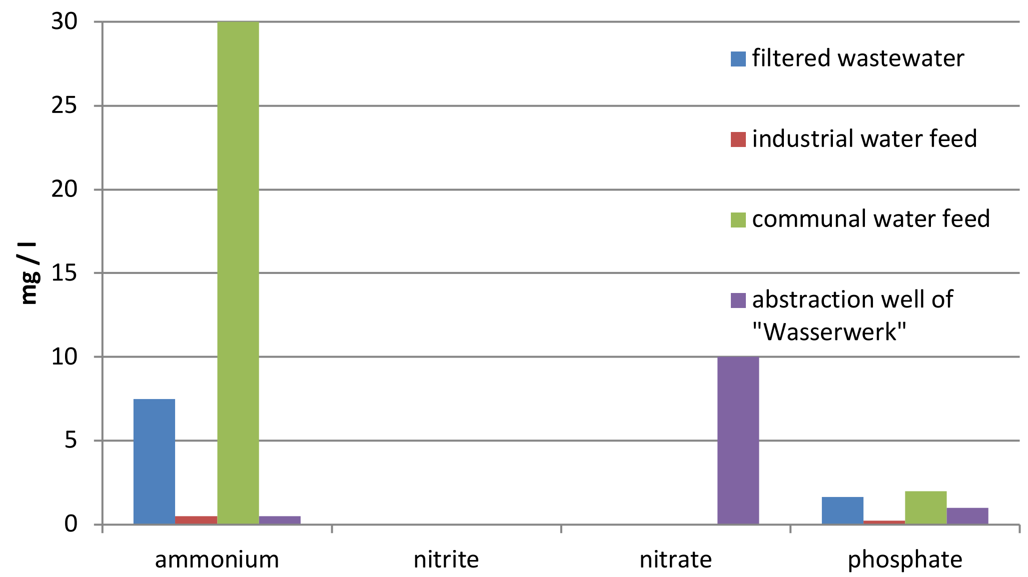


Fig. 8.7 B

Fig. 8.6 contents of minerals detected in water samples set 1, A sorted by the sampling point, B, sorted by the type of mineral

Ammonium was present in all four water samples (Fig 8.6 A, B). The sample of the communal water feed contained the highest amount of ammonium reaching 30 mg/l. The filtered wastewater still contained 7 mg/l. The other two water samples contained only a small amount. Probably the communal water feed sample location, whose water originates from every household in Cuxhaven, has the highest amount of ammonium, because ammonium is a product of decomposition of proteins as a component of faeces or of organic waste produced by bacteria (Aquaread, n.d.). The sample of filtered wastewater still contained ammonium, because it cannot be removed completely out of the water. Although appearing quite high it has to be mentioned that after the treatment the water does not have to be drinkable as the purified water flows into the Elbe after the process. The sample of industrial water feed and the sample of abstraction well of the "Wasserwerk EWE" displayed a low amount of ammonium of 0.5 mg/l. This concentration would be already toxic for fish, but not for humans (comment of the Sera aqua test instructors manual).

Nitrite was not present in any of our four water samples (Fig. 8.6 A, B). Nitrite is an intermediate product of nitrification. Ammonium only gets converted into nitrite when enough oxygen is available to start the chemical reaction of nitrification. Probably this is the reason why nitrite neither was present in the samples of communal water feed that will not contain any oxygen nor in the filtered wastewater where the nitrification process should already be completed. Furthermore, because ammonium is not noticeable present in the other two water samples, no nitrite could be present as well.

All four water samples contained phosphate (Fig 8.6 A, B). The sample of communal water feed with 2 mg/l contained the highest amount of all water samples. The industrial water feed sample had an amount of 1.6 mg/l and the sample from the abstraction well contained 1 mg/l. The lowest concentration (0.25 mg/l) was found in the industrial water feed sample.

Phosphate in wastewater mainly originates from human faeces as many foods contain phosphate, which is used for preservation and acid regulation of the food. Also cleaning agents such as dishwasher tablets contain phosphate, which is responsible for a certain part of the phosphate in the sewage water (Abwasser Analysezentrum, n.d.). These two facts could be the reason why in the communal water feed sample the highest amount was found.

Metalworking companies and the chemical industry might be responsible for the phosphate is present in the industrial water feed sample.

However, a small amount of phosphate is always present in natural waters, e.g. seen in the sample taken from the abstraction well, i.e. groundwater. The filtered wastewater still contained a small amount of phosphate, because the phosphate amount cannot be filtered completely out of the water, similar to the ammonium. Again, the water does not have to have drinking water quality as it is led into the Elbe.

Nitrate is present in one of our four taken water samples (Fig. 8.6 A, B). The groundwater sample from the abstraction well contained 10 mg/l of nitrate. This is below the general limit of 50 mg/l of nitrate in drinking water. Nevertheless, this result reflects the general excessive contamination of the groundwater in Germany (Umweltbundesamt, 2018) that already has led to prosecution by the European Justice (sciencemediacenter.de, 2018). The main cause is the nitrogen fertilisation in agriculture. The rate of nitrate, which the plants do not consume, and which is not depleted by denitrification, enters the groundwater. That could explain, why the sample of the pumping well contained nitrate but the other water samples did not.

8.4.5 Presence of iron in the samples (set 2)

Iron is present in three of our four water samples. In the industrial water feed sample 4 mg/l of iron was present, in the groundwater of the abstraction well was 2 mg/l of iron present and in the communal water feed sample was 0.375 m/l present (Fig 8.7). Iron occurs in its chemical compounds in nearly every wastewater. It is present in every body cell (Swiss Iron Health Organisation, n.d.). Through the natural loss of skin tissue, with the stool or the sweat some of the iron in the body gets lost. This is one reason why the samples contained iron; except the filtered wastewater, because iron is removed by iron exchange upon the treatment process. The iron in the sample of the abstraction well could be explained by weathering processes that make iron enter the groundwater.

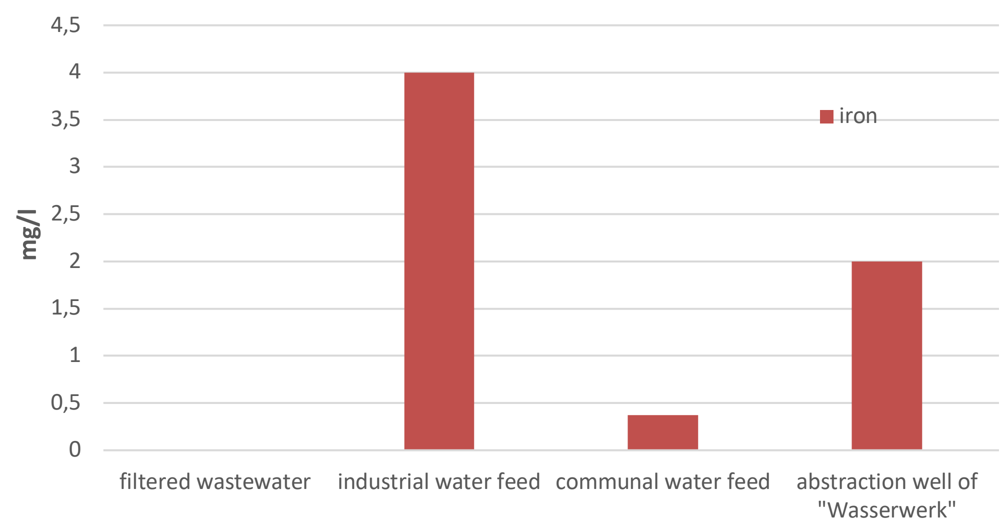


Fig. 8.7: Iron content in water samples (set 2)

8.5 Conclusion

The question aimed to answer was if our water is safe to drink. The water samples which taken in Germany contained less arsenic therefore the water could be safer to drink because its absorption into the human body over a longer period can cause heavy damage. However, in Kolkata, the work of the purification plant Serampore appears quite effective as the water sample taken at a local pumping station contained a smaller amount of arsenic than the source were the water comes from being the Ganges which has a rather high amount of arsenic.

In the next years students of our schools will retake our water samples to compare those to the ones we took the years beforehand. The present analyses did not show any danger as every determined substance was present in uncritical amounts. So it is important to try to maintain everything as it is right now or what would be even better, further decrease the amount of dangerous substances in all the water sources.
Together, we can say that both countries try to make their drinking water safe as best as possible having in mind their ecological and economical circumstances. However, possible contaminations by microplastics or hormones from pharmaceutical waste were not taken into account, hazards that only recently have been found to exist and whose extend cannot be determined so far.

9 Effects of climate change on Cuxhaven, Germany and Kolkata, India

9.1 Abstract

In this report we show the connection of water and the global climate as well as the expected changes of sea levels throughout the climate change that will impact Cuxhaven and Kolkata with respect to drinking water availability as well as the increase in spells of bad weather. Conclusively, the effects on Cuxhaven will be more dramatic than those on Kolkata, given that Cuxhaven is closer to the coast. This makes it more easily affected by sea level rises. Weather events getting more extreme would affect both regions. However, conclusions drawn have to be seen as speculations that are not easy to make about such uncertain events.

9.2 Introduction

Greenhouse gases like carbon dioxide and methane are the causes of global climate change. These gases are emitted in the atmosphere due to the burning of fossil fuels like coal and oil. The greenhouse effect on the earth is causing global warming which is gradually increasing the temperature of the earth. This has further consequences which impact the earth severely. Such consequences come in the form of melting glaciers, rising sea levels, frequent heat waves and devastation caused by storms and floods (IPCC, 2014).

Especially, Cuxhaven and Kolkata face huge and imminent risk due to rising sea levels which have been caused by melting glaciers in the polar regions as a result of global warming.

"Nearly 40 million Indians will be at risk from rising sea levels by 2050, with people in Mumbai and Kolkata having the maximum exposure to coastal flooding in the future due to rapid urbanization and economic growth, according to a UN environment report." (Hindustan Times, 2016)

9.3 Results and Discussion

Due to model projections by the Intergovernmental Panel on Climate Change (IPCC, 2014), climate extremes and their increase in frequency can be expected in the following of 21st century. Even though we know about Cuxhaven´s location and its risk of being concerned by the climate change, Kolkata has been figured out as one of the areas which are most affected by climate change and its consequences. An increase of intense rainfall, sea level rise, riverine flooding and (coastal) storm surges can lead to flooding especially during the season of the Monsoon. That is why Kolkata and Cuxhaven could be brought to a standstill for several days.

9.3.1 Effects on coastal regions as Cuxhaven

As the sea level rises, which is one of the most significant consequences of climate change, cities and villages located at the coast are exposed to very dangerous weather events such as storm surges and flooding.

The planet's average surface temperature has risen about 0.9°C since the late 19th century and the upper 700 m of the ocean show an increasing of more than 0.2°C (Society for Equitable Voluntary Actions, 2014). Due to that rise in temperature, the Greenland and Antarctic ice sheets have decreased in mass which engenders a higher presumption of cataclysms in coastal regions as Cuxhaven and surrounding locations. Thus, Cuxhaven is one of the cities where climate change will be present relatively early. An increasing sea level will change the mudflats of the Wadden Sea that are becoming dry during low tide at the moment and, presumably, change the structure of the whole ecosystem

Second, the process of ocean acidification concerns every ocean region that is why the consequence of an increase of carbon dioxide dissolved in the water is a problem for the North Sea too as the pH-value decreases. Because of this, the biodiversity concerning, e.g. crustaceans and clams, organisms relying on their lime shell, in the Wadden Sea is in danger as a low pH is diluting lime and, thus, decreasing the stability of the shells (Hahn, Jugend forscht report, 2013). The same process is found in different ocean regions which is one of the mayor problems due to global temperature rise.

Another problem which has to be considered is the drinking water salinization. A rising sea level will go along with a southwards shift of the border between saline or brackish and fresh ground water (Martens & Wichmann, 2007). As coastal regions in Germany such as abstract their drinking water from ground water, drinking water resources might become reduced. However, especially in Cuxhaven, the area used as groundwater resource is comparably large, thus, in the near future no problems should arise from that aspect for the city (pers. com. Frank Schmitt, 2019). Finally, this will depend on the final extend of sea level increase.

9.3.2 Effects on Kolkata

Approximately 10 % of world's population lives in a coastal region that belongs to the Low Elevation Coastal Zone (LECZ, area <10 m a.s.l.). As noticeable in the map, big parts of Kolkata and surrounding areas are affected by possible flooding and storm surges that occur more likely and more often due to the current sea level rise (see fig. 9.1). Those incidents concern the daily life, local economic structures and petrochemical respectively energy supply facilities. As introduced, such cataclysms can bring a standstill for the affected areas because the livelihoods that are restricted anyway can't be obtained.

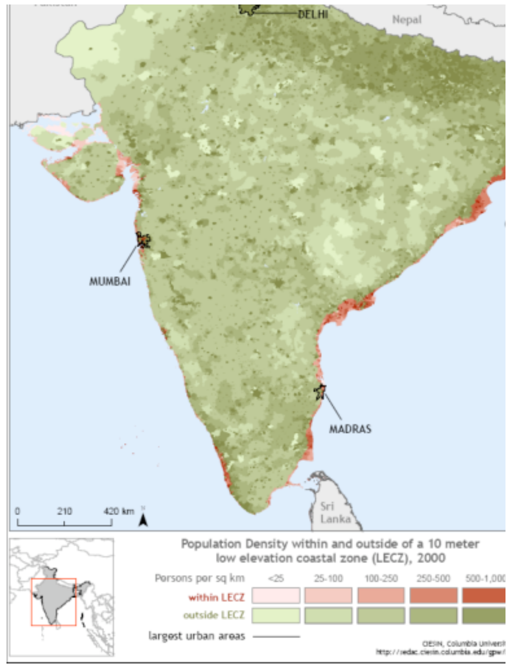


Fig. 9.1: Population density within and outside the 10 m low elevation coastal zone in India, Byravan and Rakan, 2008)

The sea level rise isn't the only consequence of the climate change that influences Kolkata in a negative way. The average values concerning temperature and the time span of heat waves are increasing rapidly. 2015 was one of the warmest years in Kolkata with climaxes of more than 45°C and the death rate caused by the high temperature increased by 44 % in difference to the year before. The heat waves are extended from May until June to April until July, and the monsoon is getting more acute (mhrescure, n. d.). Because of this, the rainwater (Fig. 9.2) is too much for the dry ground to be soaked up and is destroying the ground by flooding that are harmful for human and nature including animal as well as plants (Basu, 2015b).

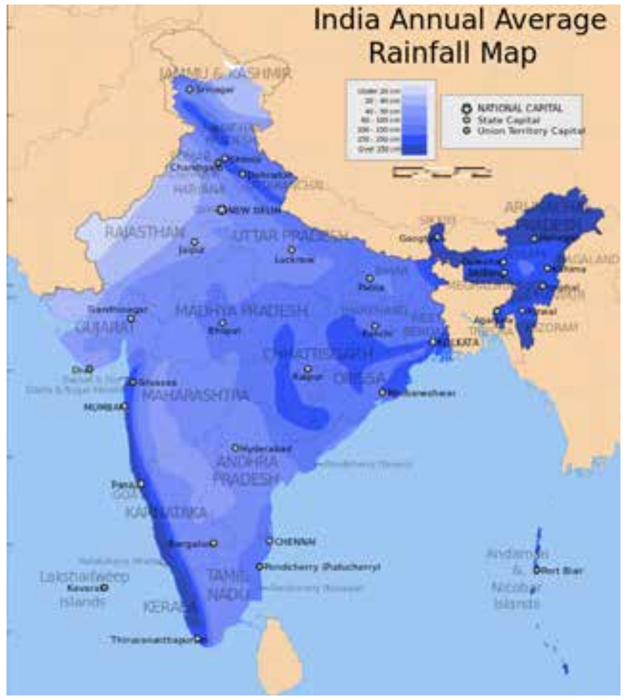


Fig. 9.2 Jährliche Niederschlagsmengen Indien (Tuschy, 2014)

NO WATER, NO LIFE – NO WATER, NO PEACE

In inclusion of the consequences for the availability and quality of drinking water, the drastic increase of rainwater leads to dirty drinking water because muddy water is confounded with water out of pipelines. Germs and bacteria can easily get into the water that should be drunk. This situation can be described by the comment "so much water and nothing to drink" that was cited upon the World Water Week 2017 (pers. com. K. Steinmetz). Additionally, the floods will increase the problems of the homeless people of Kolkata living in the streets.

9.4 Conclusion

Within the present report, different aspects of the connection of global warming and the regions of Kolkata and Cuxhaven were considered. The change of global climate will have an impact on almost every region in the world. That includes the East Kolkata Wetlands as well as the Wadden Sea. Considering all mentioned aspects, it is scientifically not possible to predict exact effects on this region. However, due to consequences such as sea level rise and warming oceans, it has to be expected that the both areas will be intensively concerned by the climate change: Cuxhaven by the increasing sea level itself effecting directly the structure of the ecosystem of the Wadden Sea and the ocean acidification mainly affecting lime shell organisms as well as, in a farer future, by salinization of the groundwater that might no longer be used as drinking water resource; Kolkata by damage due to increased floods affecting both, people and infrastructure.

Maybe, the extent of impacts is higher in Cuxhaven than in Kolkata, as Cuxhaven is closer to the sea compared to Kolkata. On the other hand, more people are affected in the Megacity of Kolkata than in the small town of Cuxhaven. Thus, numerical comparisons only represent speculations.

10 Chemical experiments on water purification

10.1 Abstract

A model experiment was conducted to demonstrate the procedure of purifying water to make it drinkable similar to the processes carried out at the water abstraction plant Serampore close to Kolkata. To produce a clear liquid the water has to repeat a process several times in which the water flows through different layers of stones, gravels, sand, zeolite and activated charcoal. Finally, chlorine water can be added to abstracted and purified water to generate chlorine.

10.2 Introduction

Disclaimer: all facts cited were provided upon the lessons held by the supervising teachers of Birla Highschool and Sushila Birla Girls School, Kolkata.

The earth is called the "blue planet" because three fourths of the earth's surface is covered with water. But how much of this water is actually fit for human consumption?

97 per cent of the global water is locked up in the oceans and the seas and is saline enough to be unfit for consumption. Out of the remaining 3 per cent, around 2.5 per cent is locked in the glaciers and is inaccessible. Hence, only 0.5 per cent of consumable water is available for us (also see chapter 2).

On the Indian perspective, the harnessed 761 cubic kilometres of its water resources, part of which came from unsustainable use of groundwater. Of the water it withdrew from its rivers and groundwater wells, India dedicated about 688 cubic kilometres to irrigation, 56 cubic kilometres to municipal and drinking water applications and 17 cubic kilometres to industry (Indian-River Catchment, 2016). The demand for water has been increasing at a high pace in the past few decades. The current consumption in the country is approximately 581 trillion litres with irrigation requirements accounting for a staggering 89 per cent followed by domestic use at 7 per cent and industrial use at 4 per cent.

Thus, freshwater is an essential aspect of human life, the water filtration plant at Serampore helps to quench the thirst of many people by providing 90 Million litres of

water to the 7 towns adjoining it .The water in the river Ganges is particularly brackish near the city, hence this location.

Flowing through the heart of the city, the water is highly influenced by excessive urbanisation and industrialisation. The industries release chemical effluents freely into the water, hence contaminating it. The water also faces the effects of over-population and over-exploitation for domestic purposes. Furthermore, it is contaminated by the fertilizers and pesticides that percolates and add onto the groundwater or directly into the river body. All these above factors result in higher turbidity and non-friendly microbes multiply in this water, making it non-portable.

Hence, the questions which arise are asking about the treatment of water and the techniques related to them. The turbidity of water has to be brought down to less than 1, the microbes need to be killed and pesticides and insecticides need to be removed so that it doesn't cause any medical problems.

A model experiment was carried out to visualize the chemical backgrounds of the processes that are applied at Serampore.

More precisely, the following questions were addressed:

- By which process chlorine water can be obtained?
- How can the turbidity be reduced?
- How does filtration of the abstracted water work?

10.3 Material and methods

10.3.1 Chemical experiment for the preparation of chlorine water

Chlorine water has to be added to the abstracted and purified water before storage for supply of households in order to eliminate microbial contamination.

A clean tube was taken and 2 g of NaCl and MnO_4 were added to the test tube. In another test tube, distilled water was kept ready with a delivery tube (Fig. 10.1 left). H_2SO_4 was added to NaCl and MnO_4 was added (Fig. 10.1 right) with a dropper and the delivery tube was immediately corked onto it.

Fig. 10.1 Preparation of chlorine water (photo: Keuser, 2019)

10.3.2 Principle of water purification

Fig. 10.2: Model experiment for the purification of water through different layers arranged in two 2-L-bottles (photo: Steinmetz, 2019).

A model experiment was set up demonstrating the basic principles of water purification from ground and surface water abstracted from the river Ganges to obtain drinkable water.

Two 2-Liter plastic bottles were cut and stuck together. The bottles were prepared with holes at the bottom of the bottle. Afterwards different layers were generated out of stones, gravels, sand, zeolite and activated charcoal. In this construction a big tube with a water sample at the upper ending was stuck and one tube was arranged at the side with an opening into a glass containing chlorine water. At the beginning of the experiment purified water was put into the water sample to flow through the construction (Fig. 10.2). Afterwards a sample taken from the Sundabans mangroves was applied.

10.4 Results

Fig. 10.3: Generation of gas bubbles indicating the formation of chlorine water (photo: Steinmetz, 2019)

10.4.1 Chemical experiment for the preparation of chlorine water

The generation of bubbles has indicated that the reaction took place and chlorine was generated.

10.4.2 Principle of water Purification

After some time, the water level within the plastic bottles filled with different layers of stones, gravel etc. was high enough so that the water could flow through the second tube into the glass with the chlorine water. The liquid in the glass is dingy, thus, the process had to be repeated several times to make it clearer.

10.5 Discussion

As stated earlier, out of the total volume of water trapped in the Indian subcontinent, 4 % of the world's water is available for human consumption which makes the water abstraction process indispensable for survival. Basically, the process of drinking water abstraction in Kolkata is composed of 5 steps:

Raw water from Ganges is abstracted. Then, it is sent to the filter house. After that, the chemical process of chlorination is done to get the water free from harmful bacteria like *E. coli* and other Coli-form bacteria. Alum is added to the chlorinated water which is sent to the flash fixer to generate the impurities in the form of foam. Henceforth the water is bifurcated into two channels for clariflocculation, where the formed particles settle down. The resulting surface water having a much lower turbidity can be it passed through the lavender channel and reaches the filter beds. The water is then sent in a single channel for post chlorination. Finally, the water is moved to the clear water reservoir, from where it is supplied to the towns (for further details see chapter 6).

The presented model experiment can visualize the chemical background of these processes.

10.5.1 Chemical background of the preparation of chlorinated water

$$2\ NaCl\ (s) + MnO_2\ (s) + 3\ H_2SO_4\ (aq,\ conc.) \rightarrow 2\ NaHSO_4\ (aq) + MnSO_4\ (aq) + 2\ H_2O\ (l) + Cl_2\ (g)$$

Manganese oxide reacts with sodium chloride and sulfuric acid to produce manganese sulfate, chlorine, sodium hydrogen sulfate and water. This reaction of generating chlorine would take place at a temperature near 100°C. The manganese oxide is the catalyst in this reaction making it possible to work at room temperature (chemiday.com, 2019).

10.5.2 Removing Hardness

Soluble salts of chlorides or bicarbonates of calcium, magnesium etc. cause hardness. These can be removed by zeolite (e.g. sodium aluminum silicate).

$$Na_2Z\ (aq) + Ca^{2+}\ (aq) \rightarrow CaZ\ (s) + 2\ Na^+\ (aq)$$

In Serampore, this function is carried out by the adding of Alum leading to foam formulation and subsequent claryflocculation of the built colloids (see chapter 4).

10.5.3 Chemical background of the principle of water purification

The insoluble impurities can be removed by several beds of gravels and coarse sand. The coloring agents, odor and other impurities can be removed by activated charcoal. The ammoniacal smell can be removed by zeolite itself. Chlorine water removes germs.

10.6. Conclusion

Chlorine can be generated by chlorine water that is added to abstracted and purified water. During the process bubbles indicated that the reaction took place.

In the process of water filtration water flows through a construction generated out of stones, gravels, sand, zeolite and activated charcoal. When the water level in the construction is high enough the water can flow out and is dingy. To earn clear water the process has to be repeated several times.

11 Reflection of the project by a participant: Different Perspectives …Same Necessities ...

Sabiha Hamid, participant of the exchange program, “no water, no life - no water, no peace”, Mon Sep 09, 2019

This exchange program which allowed me and my other fellow participants from Amandus-Abendroth Gymnasium to visit the sibling schools, Sushila Birla Girls school and Birla High School in Kolkata, since 2012 is an extension to an aim begun in 2016. This project is supposed to change the relation of students towards water and give them more awareness towards it, as it is the most basic human right known to mankind. This year the program continued with the motto “no water- no life, no water- no peace”. Because of the location of Cuxhaven and Kolkata in the tidal zone, the participating students should recognize the global importance on this significant matter. Another very good reason may also be the world peace, because believe it or not even that depends on the water supply in the future.


Fig. 11.1: Participants of the German visit to India in January 2019 in the audience hall of Birla High School (photo: Steinmetz, 2019)

This project mainly intents to promote sustainable water usage but with that it also aims to change the participants’ behaviour towards their relation to water wastage. Conclusively, sooner or later they shall share their acquired knowledge to spread more consciousness towards other people about the problem. The students should experimentally determine the physico-chemical properties of water, which makes water the basis of life on earth, and explore the possibilities and limitations of drinking water (abstraction and purification), as well as the relationship between climate change and global water availability. In addition, water samples were analysed and the quality of the different water bodies were compared. The Wadden Sea of Cuxhaven and the Wetlands near Kolkata were compared as aquatic habitats. At the same time students could learn scientific methods and scientific work. All aspects were examined in Germany, in the region

Cuxhaven and in India, in the city Kolkata. All results were discussed using literature and summarised in the form of this cumulative scientific report. In addition, the creation of our website, a video clip and a booklet will strengthen the awareness of students and the public for sustainable water use (https://cuxkata.jimdofree.com/).

Fig. 11.2 In the East Kolkata Wetlands (photo: Breuer, 2019)

Doubtlessly water is the most vital necessity of life and access to water and sanitation has also been recognized by the UN as human rights reflecting the fundamental nature of these basics in every person's life. One thing which forced me to think more about this topic would be the fact that even after being recognized as a human right by the UN General Assembly and the Human rights Council as part of binding international law in 2010 it still hasn't been a part of the 30 human right articles from UN.

Going to Kolkata and looking at the water the people use there was obviously a major shock for the most of us and after doing my first researches on the topic I got to know about the religious aspects of the holy Ganga and knowing that the people use the water for sanitation which is also holy and that they also use it to purify their souls and houses as again a bummer.

Fig. 11.3: Life in the East Kolkata Wetlands (photo: Steinmetz, 2019)

At the end I probably came to only one conclusion that if you treat a river like a God you basically ruin it you pollute it with every possible thing you can. And one of the most uncomfortable thing was carrying our own bottled water around the whole time because it wasn't safe for us to drink the water that the local drinks. Knowing that our immune system wouldn't be able to take it knowing we will get sick and knowing all of the friends we made their grew up drinking that water and

how they were obviously immune to it but how so many kids die because they don't have access to safe water to drink and for sanitation …. well I wasn't even sure what I could help to make it better for them and it is not that this problem only exists in India but it exists in many Asian and African countries as well whereas all we have to do is pay the bill and that's basically it. Imagining how the others cannot do anything against it because the politicians are corrupt and also because they aren't even aware of it themselves because even in countries where this is a problem there are the corrupt rich people who get everything they need because they have the money for it and the middle class families child has to survive only because he wasn't born with a silver spoon in mouth. Some people I talked to even said that I am exaggerating way too much but the thing is that I am not because I have been on the other side I have seen the other side I have lived on the other side. I was born in Pakistan and lived there the main part of my childhood.

Knowing that our mother Earth won't be able to survive without water does sound very depressive..? Doesn't it? And yet here we are not giving a "damn" about it in our normal lives as we know it …. but why? Only because we have access to it I guess. But as me and the other 13 participants got to know the other side, the other perspective in the 14 days we spent in India it opened a whole new vision for us. From seeing people washing themselves in the same water which they use to drink and their sanitation, for acknowledging the filtration of that water we sure opened an eye for a whole new world out there. Getting to know the use of filtration for the East Kolkata Wetlands and how it also provides food as in fish for the locals to consume at a very cheap cost.

As the time went by I started to think more and more about the water I myself waste which is a lot and coming back home and working on the reports, article and website it never left my mind I want to make a change and the change starts with me so I have tried everything in my hand to make this a world better place to live for us and our fellows who live in distant lands, a better place for our friends we have and for the ones we have not met yet.

This program definitely made us think about our necessities and the wastage we cause and also made us a lot more cautious.

12 Schlussfolgerungen & Ausblick (Conclusions & Perspectives)

Wie unser Slogan, “No water - no life, no water - no peace”, bereits aussagt, ist ohne Wasser kein Leben auf der Erde erdenklich. Und würden unsere verwertbaren Wasseransammlungen zu Neige gehen, dann würde auch der Frieden darunter leiden, mit der Folge eines Krieges um die lebensnotwendige Ressource “Wasser”.

Wasser bedeckt rund 70 % der Erdoberfläche, woraus der täuschende Gedanke entsteht, für jeden wäre genug vorhanden. Allerdings weiß man von vielen Durst leidenden Menschen ohne Wasserzugang. Die Ressource “Wasser” findet sich in Meeren, Flüssen, Seen, etc., ist aber aufgrund der jeweiligen lokalen Bedingungen und der spezifischen chemischen Eigenschaften des Wassers immer in ganz unterschiedlichem Maße aufzufinden. Wasser ist flüssig, gefroren in Form von Gletschern oder gasförmig in der Luft aufzufinden, in jedem erdenklichem Wasservorkommen ist es allerdings niemals nur der Reinstoff “Wasser”. Verschiedenste Stoffe sind in natürlichen Wasservorkommen vorhanden, entweder gelöst, wie es mit Salz häufig der Fall ist, oder vermischt, seien es größere “Portionen” von Müll oder im schlimmeren Fall Mikroplastik. Auch Nährstoffe und leider auch größtenteils von Menschen produzierte Schadstoffe verschiedenster Art lassen sich im Wasser nachweisen. Dazu haben wir unterschiedliche Versuche mit Wasserproben aus Cuxhaven (Elbe, Wasserwerke vor und nach Filtration) und Indien (East Kolkata Wetlands vor und nach Filtration) gemacht. Wasser bietet einen Lebensraum für viele, uns zum Teil sogar noch unbekannte Lebewesen, da es ideal ist, um Gase zu lösen. So enthält es Sauerstoff, der von bspw. Fischen über ihre Kiemen aufgenommen wird. Außerdem bietet es eine Grundlage für enorme und einflussreiche Ökosysteme, wie zum Beispiel das Wattenmeer oder die East Kolkata Wetlands, bei allen Unterschieden beides sogenannte “aquatische” Ökosysteme, da das Wasser den das Ökosystem prägenden Faktor darstellt.

Unsere Untersuchungen zeigten deutliche Unterschiede an Schadstoffen zwischen den Wasserproben aus Deutschland und Indien. Ein weiterer wichtiger Aspekt bei der Betrachtung der Bedeutung des Wassers sind die Reinigungsprozesse von Abwässern oder bspw. der Gewinnung von Trinkwasser. Unsere Besichtigung der bereits genannten East Kolkata Wetlands einschließlich Wasseraufbereitungsanlage und der Wasserwerke Cuxhaven, ließ den Aufwand der Reinigungsprozesse nur erahnen –Zahlen zur Menge des gereinigten Wassers in den Berichten.

Damit Wasser für den Menschen trinkbar ist, muss es also von möglichst vielen Schadstoffen befreit und vielen weiteren Faktoren zusprechen.

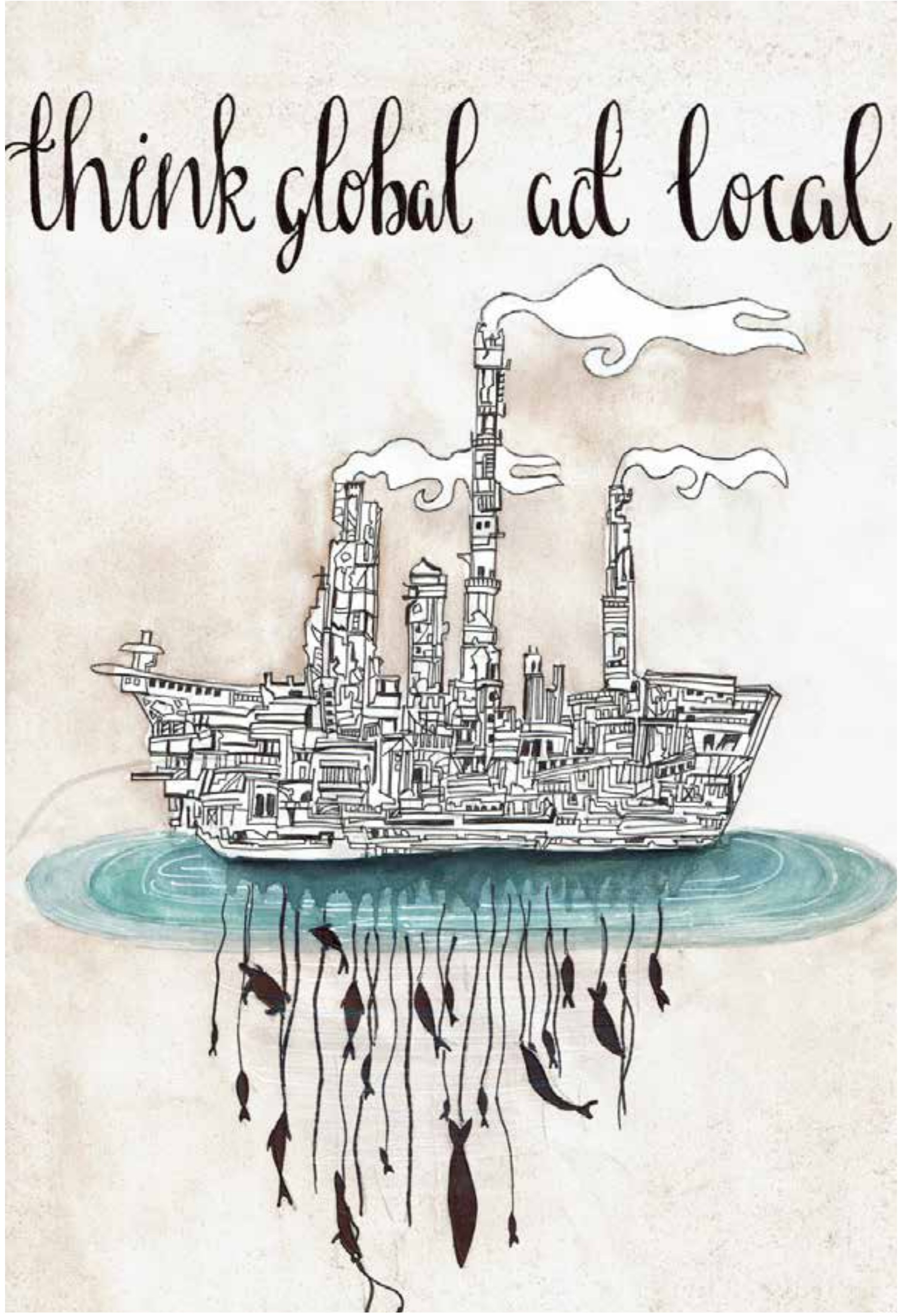
Nicht nur Wasser an sich, sondern auch Gewässer spielen eine bedeutende Rolle sowohl für Deutschland als auch Indien. Die Elbe hat in Deutschland hauptsächlich eine wirtschaftliche Rolle, da sie dem Verkehr von Containerschiffen aus der ganzen Welt zum Hamburger Hafen (HH) ermöglicht. Der Ganges hingegen hat, als einer der drei Hauptströme Indiens, eine große religiöse und spirituelle Bedeutung für Hindus. Bäder im Ganges stellen eine tiefe Erfahrung dar und auch gilt, dass Asche Verstorbener durch Vereinigung mit dem Ganges “befreit” werden vom ermüdenden Kreislauf der Geburt und Wiedergeburt.

Somit lässt sich sagen, dass Wasser eine unvorstellbare Bedeutung in vielerlei Hinsicht für Menschen hat, egal ob aus biologischen, ökonomischen oder bis hin zu spirituellen Gründen. Wasser hält uns am Leben und verbindet Menschen, obwohl es uns durch riesige Meere trennt. Der richtige Umgang mit Wasser ist schwierig, aber vor allem notwendig. Wasser gibt Leben und nimmt es, wenn Menschen darin ertrinken. Versetzt mit verschiedensten Chemikalien kann es als Medizin oder Gift wirken oder verwendet werden. Es trägt und verteilt, was sich darin oder darauf aufhält, sei es ausgelaufenes Öl oder Ähnliches, dessen Folgen zu diskutieren ein weiteres Kapitel wären. Es bleibt dabei: “Ohne Wasser kein Leben, ohne Wasser kein Frieden.”

Um beides zu erhalten ist jeder einzelne gefragt. Unsere Schule, das Amandus Abendroth Gymnasium Cuxhaven, setzt sich als Biosphärenschule ein für einen nachhaltigen Umgang von Mensch und Natur im Biosphärenreservat Niedersächsisches Wattenmeer – und damit auch für einen nachhaltigen Umgang mit der Ressource Wasser. Den zugrunde liegenden Gedanken „gemeinsam auf dem Weg zur Nachhaltigkeit“ wollen wir als Schüler/innen auch in unserer Region weiter verbreiten. So konnten wir als einen ersten kleinen Schritt unseren Schulträger dazu bewegen, Wassersparspülungen in den Toiletten einzubauen. Als zweite Maßnahme haben wir Kontakte geknüpft zur Stadtverwaltung und verschiedenen Herstellern, um das Problem der Müllentstehung durch Coffee-to-go-Becher über ein lokales Pfandsystem zu reduzieren und damit einer weiteren Vermüllung der Meere entgegen zu wirken.

Ähnlich Projekte werden auch an unseren Partnerschulen in Kolkata, der Birla High School und der Sushila Birla Girls School verwirklicht. Konkret wird dieses Schülerausrauschprojekt mit kommenden Schüler/innen-Generationen nicht nur wiederholt, sondern weiter entwickelt werden. Sie werden unsere erhobenen Daten nutzen und mit eigenen vergleichen und die begonnen Maßnahmen ausweiten. Dabei wird das Thema „no water, no life – no water, no peace“ nicht nur zusammen mit den beiden indischen Schulen , sondern im Rahmen eines EU-Projektes auch mit Schulen aus der Türkei, Norwegen, Italien und Portugal weiter vertieft.

Auch wenn unsere eigenen Beiträge „auf dem Weg zur Nachhaltigkeit“ nur kleine Schritte bedeuten, so können sie doch einen wichtigen Beitrag leisten zum großen Ganzen. Wir folgen damit dem Prinzip „global denken, lokal handeln“.



13 Impressum

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