



APPLICATION OF INNOVATIVE TECHNOLOGIES OF WATER QUALITY TREATMENT AND SUSTAINABLE DEVELOPMENT OF WATER RESOURCE MANAGEMENT

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Abstract. With the additional conditions influencing the climate change and the population growth, it has added more pressure to the problems of sewage management systems and innovative cleaning technologies. Some different approaches for more effective management of water resources are analysed in this paper. The solutions can be tested whether they have led to the sustainable development of the countries such as Turkey, by taking more attention for best practices of EU countries (for example as Netherlands). By evaluating requirements of sustainable development we are trying to extract different criteria which help to evaluate the situation in water management sector. A case study of water treatment facilities in one enterprise (the Fertiliser Complex in Turkey) is analysed. Results show how some methods such as the highest consumption of wastewater evaluation and TOPSIS can help in situation evaluation process. The most wastewater consuming production zones are determined in the Fertiliser Complex and some pollution factors are determined according to the TOPSIS method.

Keywords: water management system, sustainable development, wastewater, sewage management.

Introduction

The water pollution problems remain important in nowadays world, and issues of implementation of innovative cleaning equipment and follow the sustainable management of water resources stay very important for many countries (de Souza Fraga et al., 2019; Dzemydienė et al., 2016), and by following the goals of sustainable development (Agenda, 2015). It can be also regarded that some countries suffer more from their water reservoirs due to their infrastructure and population extension. For example, the most known and populated cities in Turkey has been suffering from the lack of water of good quality nowadays. Multiple solutions related with water resource management problems are found in literature, but situations for protection of pollution in the world still remain very actual (Lubin & Esty, 2010; Lozano, 2012; Dzemydiene & Askarova, 2019).

This research is focused on the approach of evaluation of water technologies by determining the sources of the polluted water and takes further to a lead for the sustainable development. “Beside the increase in agricultural and domestic water demand, industrial water demand is also rapidly increasing parallel to industrial developments and that creates a pollution problem over the water resources” by (Cakmak et al., 2007).

The problems are arising with the capacities of infrastructure of cleaning equipment development as well as the increase of factors which cause heavily pollution of the sewage systems of the countries (Russo et al., 2014). An example of Dutch practice have been confronted with severe water-related problems, which are the result of an unsustainable water system, arising from human interventions in the physical infrastructure of the water system and the water management style.

The factors of housing industry, infrastructure and agriculture have resulted in increasing pressure on the water system (Brugge et al., 2005). The case study of enterprises in Netherlands as a country that is beneath can help to found more competitive experts, which help to deal with severe sewage problems. Such examples show how innovative means can led to the results of sustainable development in water management sector.

The aim of this study is forwarded for determination of different water management technologies, which can be applied for waste water cleaning. The tasks are formulated for description of some solutions of technological platforms for cleaning wastewater and through the representation of flow diagrams, water mass balance of wastewater in the company. The application of multi-criteria decision making method such as TOPSIS, allow us to find out evaluation possibilities of water usage and evaluate the effectiveness of plant management. A comparative review of enterprises in Turkey and Netherlands help to contribute in management activities forwarding efforts’ to sustainable

development requirements of enterprises. The results are demonstrated by applying of some water quality control technologies. The management action plan is developed in wastewater management sector under the perspective to apply the best practice of Netherlands for other development countries forwarding actions for more sustainable development in water sector.

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Evaluation results are demonstrated on the wastewater consumption analysis provided by the Fertiliser Complex in Turkey.

1. The case study of application of water cleaning technologies under the perspective of sustainable development

Some case studies are analyzed for better understanding of influence for sustainable development of the best practices of water cleaning technologies. For example, the management of Dutch water sector has been recognized worldwide for its capabilities to control coastal and inland water in order to guarantee safety and maintaining reliable water functions for agriculture, shipping, and industry. Being a river-delta and having more than 50% of land beneath sea-level, the Dutch have a century-long tradition of fighting with the water pollution and trying to control it (Brugge et al., 2005).

In 1993 and 1995, the Netherlands experienced two major floods of the rivers Meuse and Rhine, followed by high level of regional waters in 1998. The sudden water related problems led the Parliament to question of current water management practices (Brugge et al., 2005). Three years later, the flood of the Meuse river happened again.

All of the members of the government had agreed on the issue of their existential way is not enough to avoid these floods as well as they passed to new regulations and tried to find out different mechanisms. However, to solve out a problem, need to cover the question of what is the main resource of the flood.

The Dutch has investigated that their water can be characterized as a transition (Brugge et al., 2005). As a result, they have constructed some innovative approaches. The technologies used in this project are the alternative local sources for residential water supply, using the and floating urbanisation (De Graaf et al., 2011). The precautions of Dutch people offer for the better supply of water are presented in Table 1.

Table 1. The precautions of Dutch people offer for the better supply of water (source: prepared by (De Graaf et al., 2011))

Examples of provided actions	Detailization of activities
Water retention	Green roofs, water retention square, Infiltration facilities
Decentralised sanitation and reuse	Separate collection of urine and other wastewater stream
Alternative sources of water supply	Rainwater and stormwater, local surface water, local groundwater

2. Influence of physical effects of pollution of wastewater to other activities in Turkey

Economically available surface and groundwater potential in Turkey is about 110 billion m³ (Cakmak et al., 2007). This potential's 95 billion m³ is coming from the inborn rivers and 3 billion m³ is coming from out out-coming rivers and 12 billion m³ comes from groundwater resources. The problems of Turkey's wastewater can be subdivided under three different areas such as physical, water quality and water pricing.

Annual average domestic waste water potential of Turkey is about 3,7 km³ and industrial wastewater potential is 3 km³ (Cakmak et al., 2007). According to these statistical data, the country's wastewater potential is not sufficient. The issue is the lack of well treatment for the wastewater and it results to mix with the potable water and causes some severe sicknesses in the country.

Alternative water resources should be developed to eliminate the water problems whereas drainage and sea water can also be used for this purposes (Cakmak et al., 2007). Turkey is covered with three different seas which are named as the Mediterranean, Marmara and the Aegean, however during the summer time, it is forbidden to swim in the city centers of Istanbul and Izmir which are connected with the Marmara and the Aegean Sea. In the south of the country, Antalya shares the possibility to swim in the Mediterranean Sea (Figure 1). So large treatment plans are definitely necessary for this country if they want to give access to the citizens of Istanbul and Izmir to be able to swim in the centers. On the other hand, these measures might result with a positive impact on the sustainable development. In Istanbul, a research went through the water pollution with respect to some questions which is answered by the citizens (Seker et al., 2010).

The questions are about to test of the awareness of the citizens of Istanbul from Asian continent and European continent. The most significant one is, mean for explaining and showing the sensitivity the sea pollution in Turkey (Seker et al., 2010).

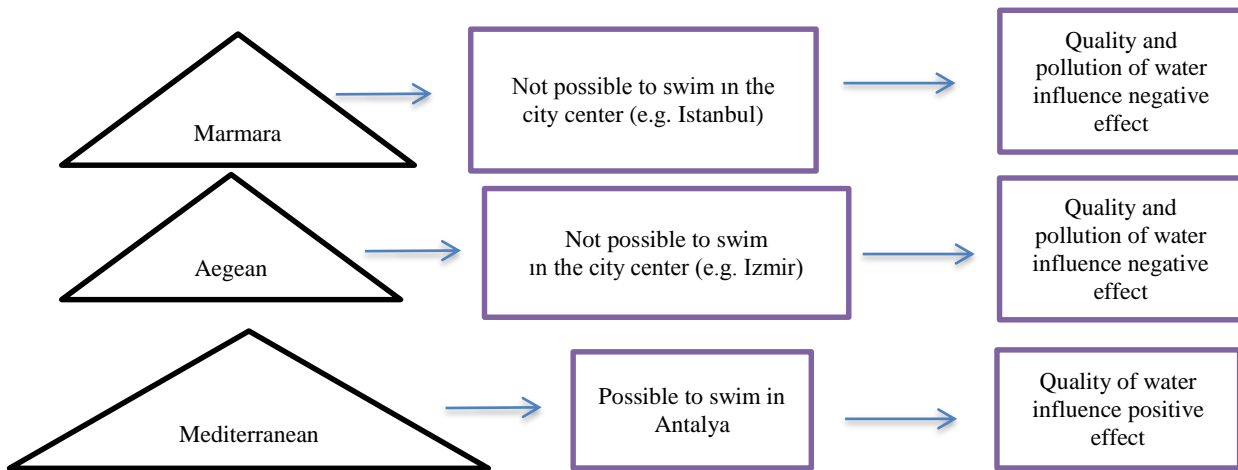


Figure 1. The relation of the pollution of water of seas in Turkey with possibilities of other activities

The answer turns out to be, with respect to the level of increase in the education, the people turns out to be more conscious and more sensitive about the water pollution.

3. An example of evaluation of water quality effects by wastewater cleaning possibilities of case study of business enterprise in Turkey

By analysing water pollution in rivers, lakes and seas some factors are revealed. Production growth influence the level of rapidly increasing parallel the population growth, and pollution is increasing by the factors of urbanization, industrialization, agricultural chemicals and fertilizers (Cakmak et al., 2007; Altunbilek, 2006). Dimensions of water pollution and various consequent environmental problems will increase due to increasing pesticide and fertilizer utilization in GAP project area. For the elimination of these kinds of problems, farmers and implementers should be conscious and use unharmed and easily biodegradable pesticides. The GAP area is been considered as the least practical experience area of Turkey. As the referenced authors mentioned about the fertilizer utilization, the place where was practiced, is the only responsible for such utilization. It is needed to mention about the biggest private sector investment in Eastern Anatolia.

In Turkey, the ratio of the factories with a wastewater treatment service is only 9% so it can be said that the issue of wastewater is not taken seriously in this country. About 141 of 3215 municipalities have a sewage system and only 43 of them have a treatment facility (Cakmak et al., 2007).

The Fertilizer Complex that is called as “ETIBAKIR” is established in 1974 to fulfil a portion of Turkey’s phosphate fertilizer needs and specifically to contribute to the sustainable development of Turkey by creating employment (Etibakir Fertiliser Complex, 2018).

The average data of distribution of wastewater of the business enterprise of “Fertiliser Complex of ETIBAKIR” is presents in Table 2 by analysing official data of enterprise, during the practice in 2018 year.

Table 2. Data on dynamics of the different kinds of water which are going to be used in the plant (source: Official data of the enterprise ETIBAKIR Fertilizer Complex, 2018)

Kinds of water	Flow as m ³ /h	Design as m ³ /h
Demineralized water	116	150
Potable water	42.1	65
Soft water	355	445
Raw water	405	1.215
The total amount of water that Plant needed	925	2097

The plant is capable of producing of 550.000 tons of phosphate rock per year. In addition, the enterprise as “Fertiliser Complex” has a perfect wastewater treatment system and distributes the cleaned water for the reutilization as the loop goes in this way for the factory. An explanation of such wastewater treatment and structure of all processes in details is presented in Figure 2.

The distribution of wastewater is divided into 3 different categories as the potable water, soft water and the demineralized water. These treated wastewater types have been separated into different production plant zones. Implication of one significant issue is that the Cooling Tower Plant is responsible for the cooling section for the phosphoric acid production.

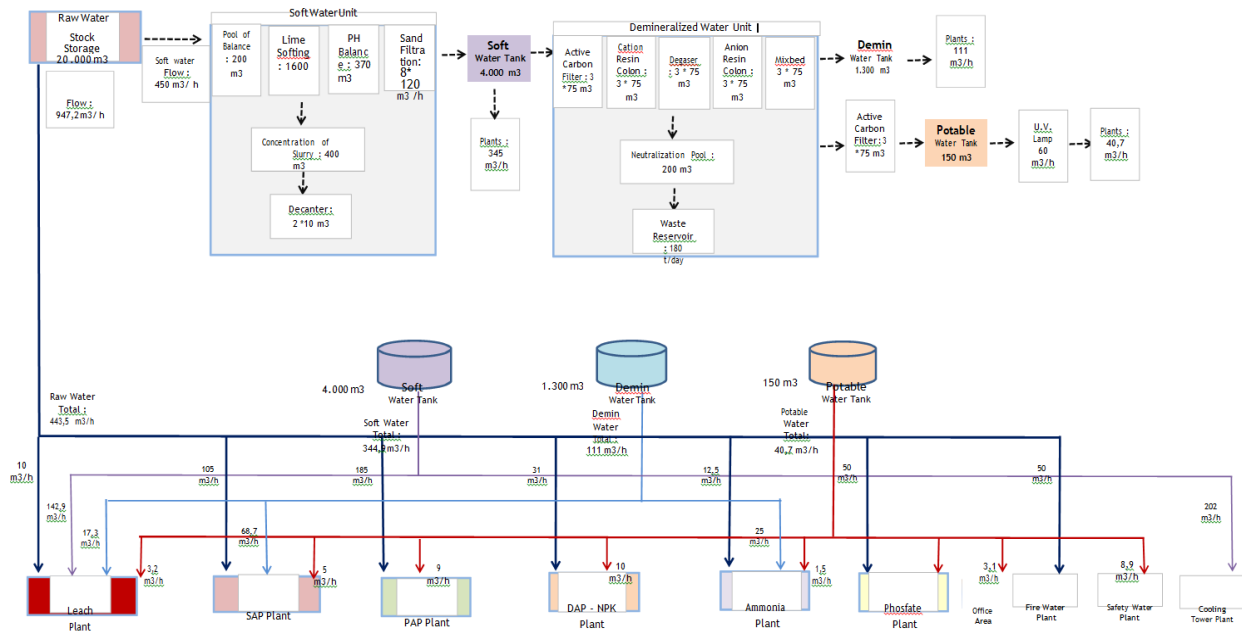


Figure 2. The structure of waste water treatment and data flows in the plants of the business enterprise – “Fertilizer Complex of ETIBAKIR”

Due to increasing of the temperature of production process up to 150 °C, the system needs to decrease this temperature. Since there is not a river or sea existing in the mentioned area, the major water consumption belongs to there. It can be seen that sulfuric acid production plant is consuming a lot of water during the sulfuric acid production.

4. An analysis of the highest wastewater consumption of used water in four different production zones of analysing enterprise by using TOPSIS

For analysis of the wastewater consumption in the enterprise, the TOPSIS method is analysed as one of most applicable. The evaluation of the highest wastewater consumption for four different plants will be determined according to TOPSIS method (Zavadskas et al., 2016). The primary data are achieved from previous work, while calculating the steps, which are accomplished with the respect to the input level of water and the output level of water which can be also classified as the mass – balance equation:

Input + Generation = Output + Accumulation + Consumption. In Figure 3 data are given according to the three Production Zones that cover Phosphoric Acid, Sulphuric Acid and Ammonia Plant.

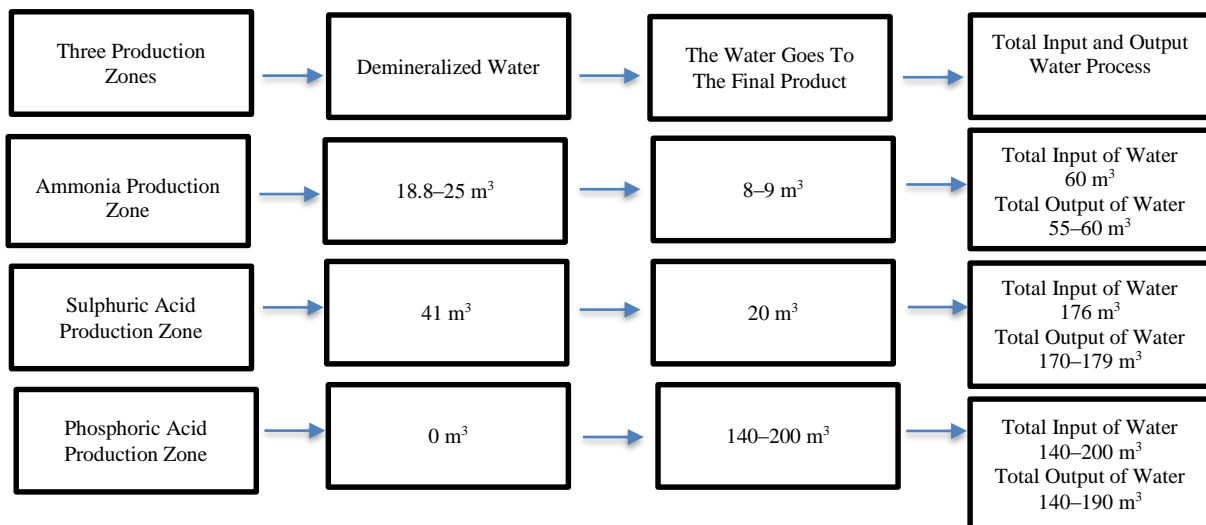


Figure 3. Schema for distribution of input and output of wastewater from the Phosphoric Acid, Sulfuric Acid and Ammonia Production Zones in the enterprise

The aim of TOPSIS is to find out, the highest water consumption according to the most water consumption. The Leach Plant is given in Figure 4 with respect to the different types of water consumptions. In these figures, it can be observed that all of the data for the Phosphoric Acid, Sulphuric Acid and Ammonia Plant are from the same parameters, however in Leach Plant, detox water and the water that will appear at the end of the neutralization is given. According to the, these parameters, with the help of TOPSIS, the maximum wastewater consumption only for one plant will be determined.

The illustration of water mass balance of the Leach Plant of the ETIBAKIR Fertilizer Complex, is presented in Figure 4. The table below is from an example of the water circulation of the Leach Plant where the different types of water can be seen in a divided section such as water coming to the process input, water output end of the process. The water regarding to the process input includes washing, soft, demineralized, drinkable and the sum of the whole input. The water output at the end of the process has also the water that comes through out of neutralization, detox, water going to the product, water which is condensated during the process and the sum of the whole output. From the total water input value (169.4 m³/h) and the total output value (160–169 m³/h), the mass balance can be confirmed since both values are almost the same.

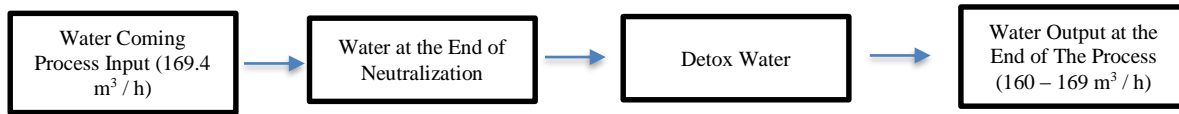


Figure 4. Illustration of water mass balance according to the Leach Plant of the enterprise – the ETIBAKIR Fertilizer Complex, by empirical research period, 2018

4.1. Formal description of TOPSIS method

This part of the study is for the description of TOPSIS method following by (Hasson & Ibrahim, 2013; Zavadskas et al., 2016). The main purpose of this method is to choose the most suitable option from other alternatives. In this method, there is a matrix which consists from alternatives, criteria and weights which shows criteria's level of importance. Alternatives can be any choices, solutions or name of product, and all criteria are indicators, which evaluate the alternatives.

By following (Hasson & Ibrahim, 2013), the first step needs to evaluate the normalized decision matrix. The TOPSIS should use the vector normalization.

At first stem the normalized decision matrix is calculating by using this formula according to (Hasson & Ibrahim, 2013):

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (w_1 + w_2 + \dots + w_n = 1), \quad (1)$$

where, n_{ij} – normalized criteria, $X = (x_{ij})$ – a decision matrix, $W = (w_1; w_2; w_n)$ – set of weights of criteria, $x_j \in R$ – all numbers. The weights are assigned by reviewing opinions of experts (Hasson & Ibrahim, 2013), calculating the weighted normalized decision matrix:

$$v_{ij} = w_j n_{ij}, \text{ for } i = 1, \dots, m; j = 1, \dots, n, \quad (2)$$

where w_j – the weight of the j -the criterion.

By following (Hasson & Ibrahim, 2013), determining the positive ideal and negative ideal solutions.

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left(\left(\max_i v_{ij} \mid j \in I \right), \left(\min_i v_{ij} \mid j \in J \right) \right); \quad (3)$$

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left(\left(\min_i v_{ij} \mid j \in I \right), \left(\max_i v_{ij} \mid j \in J \right) \right), \quad (4)$$

where I is associated with benefit criteria and J with the cost criteria, $i = 1, \dots, m; j = 1, \dots, n$.

Calculating the separation measures from the positive ideal solution and the negative ideal solution:

$$S_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_i^+)^2}, \quad i = 1, 2, \dots, m; \quad (5)$$

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_i^-)^2}, \quad i = 1, 2, \dots, m.$$

Calculating the relative closeness to the positive ideal solution:

$$P_i = \frac{S_i^-}{S_i^- + S_i^+}. \quad (6)$$

The ranking is assess by the order of solutions. The last step will be the determination of the lowest and highest value according to the negative and positive ideal solution.

4.2. Evaluation of the highest wastewater consumption with respect to the water mass balance

Theoretically it is concluded that the Sulfuric Acid Plant has the most wasterwater consumption, this statement has been clarified by official data of analysing enterprise. At first stage, four different production plants have been chosen, these plants are named as Phosphoric Acid, Sulfuric Acid, Ammonia and Leach. Firstly, they have been classified with different criteria such as demineralized water, potable water, total water input and total output of the used water. The weights have been given through the importance of the criteria. All primary data are from the Fertiliser Company called ETIBAKIR in the Southeast of Turkey (Etibakir Fertiliser Complex, 2018). This enterprise is working under four different production zones, which are called as Phosphoric Acid production, Sulfuric Acid production, Leach plant, and Ammonia production unit. The data is based on empirical research results provided in December of 2018 year by Batuhan Akçer of his practical work in the Phosphoric Acid production unit in position of process engineer (Etibakir Fertiliser Complex, 2018).

The decision matrix is based according to the types of used water, such as drinkable, demineralized and the total input of water coming through the production zones within the total output (Table 3).

As well as, sum squares and square roots have been taken in the Table 3, according to the primary data from the decision matrix. The weights have been asked with respect to the experts as chief engineers working in these 4 production zones: the Phosphoric Acid production, the Sulfuric Acid production, Ammonia plant, and the Leach plant of the analysed enterprise. The providing evaluation values of weights are averaging, and presented in Table 3. Also normalized values based on the division of the datas from Table 3 with the square root again taken from Table 3, can be found in Table 4. In Table 5, the detemination of the positive ideal solution has been shown with respect to the lowest value whereas Table 6 is representing the negative ideal solution according to the highest consumption of wastewater.

Table 3. Primary data for decision matrix according to the consumption of wastewater from four different production zones with evaluation of weights and with sum squares (source: Official data of the enterprise ETIBAKIR Fertilizer Complex, 2018)

Weights			0.1	0.2	0.3	0.4
Criteria	Duration	Unit	Demineralized water	Drinkable water	Total input of water	Total output of water
Used water in Phosphoric Acid production	1 day	m ³	0	9	150	140
Used water in Sulfuric Acid Production	1 day	m ³	20	10	176	170
Used water in Leach plant	1 day	m ³	17.3	0.1	169.4	160
Used water in Ammonia plant	1 day	m ³	18.8	10	60	55
Sum Square			1052.3	281	85772.36	77125
Square Root			32.4458	16.76335	292.8691858	227.7138815

With respect to the used water in four different production zones, the decision matrix has been constructed. The data are provided according consumption average need of 1 day duration of production where the unit is taken as m³. According the the the values on the Table 3, the Plant that is needed the most water is the Sulfuric Acid Production Zone and in case of the drinkable water, Ammonia Plant and Sulfuric Acid provides the maximum amount for their workers and engineers.

The normalized values for the Table 4 is consisted from a division where the nominator is the values coming from Table 3 and where the denominator values are coming from the square root values again from the Table 3. In Table 4, it can be seen that the normalized values of the drinkable water for the Sulfuric Acid Production and Ammonia Plant are the same. The least value for the drinkable water belongs to Leach Plant due to their high use of different chemicals during the production which pollute the water.

Table 4. Normalized values of the decision matrix

Weights	0.1	0.2	0.3	0.4
Criteria	Demineralized water	Drinkable water	Total input of water	Total output of water
Phosphoric Acid Production	0	0.536885435	0.51217406	0.50411596
Sulfuric Acid Production	0.61641258	0.596539372	0.600950897	0.612140809
Leach Plant	0.53319688	0.005965394	0.578415239	0.576132526
Ammonia Plant	0.579427829	0.596539372	0.204869624	0.198045556

Table 5. Positive ideal solution according to the TOPSIS method

Weights	0.1	0.2	0.3	0.4		
Criteria	Demineralized water	Drinkable water	Total input of water	Total output of water	Sum of the rows for each plant	Square root of the sum of the rows
Phosphoric Acid Production	0	0.107377087	0.153652218	0.201646384	0.006518	0.080737
Sulfuric Acid Production	0.061641258	0.119307874	0.180285269	0.244856323	0	(Lowest value) 0
Leach Plant	0.053319688	0.001193079	0.173524572	0.23045301	0.014274	0.119472
Ammonia Plant	0.057942783	0.119307874	0.061460887	0.079218222	0.041569	0.203885
With positive ideal solution						Lowest value should be taken

TOPSIS method is separated into two different ideal solutions, named as the positive and negative. Positive ideal solution calculation is shown in the Table 5. According to the “lowest value should be taken” sentence, the value of the square root of the sum of the rows for the Sulfuric Acid Production is the positive ideal solution. With respect to the Table 5, it can be seen again the positive ideal solutions for Sulfuric Acid Production and Ammonia Plant are the same which signifies that both have similar consumptions of water. In addition, from this table, it can be understood that the Phosphoric Acid Production does not use any demineralized water during their production of Phosphoric Acid.

Table 6. Negative ideal solution according to the TOPSIS method

Weights	0.1	0.2	0.3	0.4		
Criteria	Demineralized water	Drinkable water	Total input of water	Total output of water	Sum of the rows for each plant	Square root of the sum of the rows
Phosphoric Acid production	0	0.011275044	0.008499241	0.014988655	0.034763	0.186448
Sulfuric Acid production	0.003799645	0.013951105	0.014119234	0.027435981	0.059306	Highest Value 0.243528
Leach Plant	0.002842989	0	0.012558269	0.022871961	0.038273	0.195635
Ammonia Plant	0.003357366	0.013951105	0	0	0.017308	0.131562
With negative ideal solution						Highest value should be taken

Thus, the negative ideal solution is taken from the highest value, coming from the square root of the sum of the rows in Table 6. Also from the Table 6, it can be concluded that in the negative ideal solution, the amount of drinkable water for the Sulfuric Acid Production and Ammonia Plant are the same. For the usage of demineralized water according to the Table 6, the most consumption belongs to the Sulfuric Acid Plant. Both positive and negative ideal solutions result, Sulfuric Acid Production unit has the highest wastewater consumption as the highest value in the negative ideal solution belongs to them and in the positive ideal solution, the lowest value also corresponds to this production unit.

Conclusions

Current legal framework relevant to water resources management in Turkey is not sufficient for an integrated management. That is why, a legal regulation is definitely needed. The database is coming from the previous work

experience in South Eastern Anatolia, the complex is known as the biggest private sector investment in the region so a treatment is essential. Thus, the “WWTP” which can be named as the wastewater treatment plant takes care of multiple production zones by only themselves, so this is a quite huge work and it should not be forgotten that they are doing this loop every single day. In this article, it is needed to be declared that Turkey has severe problems for the treatment cases, as the private sector investments like this increase, that the number of the wastewater treatments will also start to gain importance. ETIBAKIR “Fertilizer complex” investment has really increased the sustainable development of Turkey, as in the agriculture sector, nowadays farmers can use their own fertiliser which are produced in their country. Agricultural sector has the greatest share among the water user sectors of Turkey. So, the utilization of tools and technologies providing effective water utilization in agriculture in well compliance with environmental regulations should be among the prior objectives of the country.

In this study, TOPSIS method help to find out the highest consumption of wastewater in the production zones quantitatively, both the negative and the positive ideal solutions have resulted as the top usage of wastewater belongs to Sulphuric Acid Production. Based on the results of TOPSIS, it can be concluded that in the four production zones of the ETIBAKIR Fertiliser Complex, the used water in the Sulfuric Acid Production has the highest consumption of water. As it can be seen, the complex has different kinds of water such as demineralized, drinkable. In Turkey, drinkable water is a significant problem that it is almost impossible to be able to drink from the tap. With the increase of such private investments in different regions of Anatolia, water can be divided into demineralized and drinkable where it can also effect to the quality of water in a positive way.

Urban water systems are facing the challenges of on going urbanisation, climate change and increasing societal demands. Over the last decades, various approaches have been developed to respond to these challenges. These approaches generally focus on source control and local solutions of dealing with stormwater and water supply. Reliable technologies for a more sustainable in urban water management sector are currently available. The water-related problems in the Netherlands are the result of the whole of human interventions in the water system over the last century. Large-scale societal trends, physical processes and human interventions have led to increasing pressure from the land on the water and increasing pressure from water onto the land. The water system, both the physical infrastructures as well as the water governance system, has become unsustainable in terms of reduced safety, costs and ecological damage, and in which the floods are mere symptoms of these deeper fundamental problems.

In the part of physical effects of the wastewater in Turkey, it is mentioned that in two major cities of Turkey (Istanbul and Izmir), it is not possible to swim in the city centres. However, in the South of the country, it is accessible to swim. Municipalities of Izmir and Istanbul should have a discussion with the municipality of Antalya to solve the pollution and biological factors. If this case can be solved it will have a direct effect on Turkey’s sustainable development whereas people will be less tired in the summer’s hot weather. It will also have an effect on the quality of the daily life for the citizens.

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