Monitoring system for electricity consumption at pumping stations

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Monitoring system for electricity consumption at pumping stations

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Abstract. Currently, the control and accounting of electricity at 1693 irrigation pumping stations of the Ministry of water management of Uzbekistan is carried out manually, on the basis of which 17 different types of documentation are filled in. This work requires a large amount of time and human resources. This can also be observed at the water and wastewater pumping stations. In this paper, the existing system of accounting for electricity consumption is fully considered on the example of several irrigation pumping stations and one regional management of pumping stations. The organizational structure and the procedure for maintaining documents on accounting and collecting information about the electricity consumed by pumping stations were analyzed. Based on the data obtained, an automated system for monitoring and accounting of electric power at pumping stations has been developed. This system eliminates unauthorized switching on pumping units, theft, or inefficient power consumption. As a result, it reduces the annual electricity consumption of pumping stations, and also reduces labor costs. The payback period for the introduction of an automated system for monitoring and accounting of electric power at pumping stations is 2.5 months.

1. Introduction

In various fields of activity, they try to implement a system for monitoring electricity consumption, as a result of which it becomes possible to spend it effectively [1,2,3,4,5]. Some papers indicate the advantage of on-line electricity metering to reduce the cost of production [6,7,8,9,10]. It is known that the energy-efficient operation of a pumping station is also affected by the operating modes of pumping units [11,12,13,14]. The introduction of an automated accounting and control system for electricity at some pumping stations in other countries has shown its effectiveness [15,16,17].

Currently, in Uzbekistan, 4.3 million hectares of irrigated land, 2.3 million hectares are provided with water supplied by pumping stations. Machine irrigation is one of the key sectors of the country's water economy in terms of capital expenditures and infrastructure development [18,19,20,21,22]. More than 5301 units of pumping units have been installed at 1693 pumping stations that are on the balance of the Ministry of water management (MWM) of the Republic of Uzbekistan. With a total capacity of 7.9-8.0 million kW, the total capacity of these pumping stations is about 7000 m^3/s.

Pumping stations account for a significant portion of the electricity consumed for agriculture. The total annual energy consumption of pumping stations that are on the balance of the Ministry of water management is 8.0 billion kW·h or about 12.5% of the annual electricity generation of the entire energy sector of Uzbekistan. If we additionally take into account the pumping stations that are on the balance of farms and dekhkan farms, the energy consumption figures become even more significant.

Therefore, we believe that the introduction of an automated system for monitoring electricity consumption at reclamation pumping stations in Uzbekistan is relevant and economically feasible.

2. Materials and methods

The purpose of the study is to improve the system of monitoring and accounting of electricity consumption at pumping stations by means of its automation.

The following research objectives were set:

- study of the structure of monitoring and accounting of electricity consumption at pumping stations;
- study of all types of documentation to be filled in when monitoring electricity consumption;
- analysis and calculation of labor costs for monitoring and accounting of electricity consumption at pumping stations;
- development of an automated system for monitoring and accounting of electricity consumption at pumping stations.

The object of research is the Jizzakh head pumping station, the Nurafshon, and Suvchi pumping stations of the Syrdarya region, as well As the Department of pumping stations and energy at the Chirchik-Akhangaran Department of irrigation systems of the Tashkent region.

The subject of the study is the system of monitoring and accounting of electricity consumption at pumping stations.

The main results of the work were obtained by analyzing the organizational structure, keeping records and collecting information on electricity consumed at pumping stations, and calculating the economic efficiency of implementing an automated monitoring system.

3. Results and Discussions

Currently, the number of personnel at the pumping stations of the Ministry of water management is about 16,000 people or 40% of the employees of the entire Ministry. It is expected to reduce the number of production employees of the Pumping stations and the energy Department (PSED) by 14%. The monitoring of electricity consumption at pumping stations is carried out on the basis of numerous documents (Table 1).

All documents listed in Table 1 are generated manually. Information about the operation of pumps and their indicators are recorded in the following logs:

- Log of electricity consumption (indicators: date, meter reading, the difference in indicators, current transformer difference, consumption (kW·h), name of the duty officer, a signature of the duty officer, a signature of the head of the Department).
- Log of delivery and reception of pumped water using the pumping station (indicators: date, start-up time, shutdown time, operation (Moto/hour), pumped water (m^3), duty electrician, duty signature, water user, water user signature).
- Motor monitoring log (indicators: date, active power P1, active power P2, operating time T, energy saved).
- Log of telephone messages and orders.

Table 1. List of documents for monitoring electricity consumption

Document name	Content of document	The frequency of the report generation	Performers	Form of saving, transferring
An agreement on the use of electricity	Setting a monthly limit on electricity consumption	once a year	The district Department of irrigation; Territorial electric grid company (TEGC) of the Ministry of the energy of the Republic of Uzbekistan	on paper
Summary form "Established contractual value of electricity consumption" for basin management of irrigation systems»	Formation of consolidated limits for district irrigation departments based on No.1	once a year	PSED; TEGC	on paper
Summary form "Set contractual value of electricity consumption" for MWM	Formation of consolidated limits for basin management of irrigation systems based on No.2	once a year	MWM, ME	on paper
Operational information about power consumption at the pumping station	Collecting data from meter readings installed at the pumping station	Daily	Pumping station	log entry, phone transfer to PSED
Summary of operational data on electricity	Generalization of the received data from	Daily	PSED	log entry, phone transfer to MWM

consumption at pumping stations	pumping stations based on No.4			
Summary of operational data on electricity consumption at pumping stations	Summarizing the data received from PSED based on No.5	Daily	MWM	Excel document
Information about operating pumping units	Collection of data on operating pumping units and their output compared to last year's data	Daily	Pumping station	log entry, phone transfer to PSED
Summary of operating pump units for PSED	Generalization of the obtained data on operating pumping units and their output in comparison with the data of the previous year for PSED based on No.7	Daily	PSED	log entry, phone transfer to MWM
Summary of operating pumping units by MWM	Summarizing the data received from PSED based on No.8	Daily	MWM	Excel document
Report on power consumption at the pumping station	Generating a report on electricity consumption	five-day, monthly, quarterly, annually	Pumping station	on paper, transfer to TEGC
Operational information about power consumption at the pumping station	Generating a report on electricity consumption based on No.4	five-day, monthly	Pumping station	on paper, transfer to PSED
Summary of operational information about power consumption at pumping stations	Generalization of the received data from pumping stations based on No.11	five-day, monthly	PSED	on paper, transfer to MWM
Summary of operational	Generalization of the data	five-day, monthly	MWM	Excel document

information about power consumption at pumping stations	obtained from PSED, based on No.12			
Analysis and forecast of electricity consumption by limit	The analysis of electricity consumption by the set limit is carried out and the forecast of electricity consumption by the end of the month is determined	25th of the month	PSED	Excel document
The requirement to change the monthly limit of energy consumption by pumping stations	Creating a request letter to MWM to change the monthly limit within the quarterly consumption volume	25th of the month	PSED	on paper, transfer to MWM
Changes in the "contractual values" (limits) of electricity consumption by pumping stations	A Fax message is generated about permission to change limits based on No.15	As necessary	MWM	on paper, transfer a Fax message to PSED
The requirement to change the monthly limit of energy consumption by pumping stations	Formation of a letter of permission to the Regional power grid management to change the monthly limit based on No.16	As necessary	PSED	on paper, transfer to the Regional power grid management

Taking into account the number of documents generated in all pumping stations (with different frequency-daily, five-day, weekly, monthly), a huge number of units of information is obtained, which is received, processed, and transmitted. These procedures, while not automated, cause extremely large losses of working time.

At pumping stations, information about the operation of pumps and units is collected manually. In larger pumping stations, devices (meters) for displaying electricity consumption and pumped water are installed directly in the vicinity of the station's management center. It does not take much time to remove (register) instrument readings.

In small pumping stations, the collection of these readings is a time-consuming job. Because the pumping units are installed 2-3 km away from each other along the channel line (for example, the

«Suvchi» pumping station operates 13 pumping units located 20 km along the canal). To take readings of the electric meter, the duty electrician goes around all units every day for up to 6 hours. The detour will take 2 hours of time and transport costs. The collected data is entered in the appropriate logs, computational work is carried out and the duty officer transmits this data to the PSED by phone.

Correspondence between pumping stations and PSED is carried out exclusively by telephone. Management information is received in the form of a telephone message. The address of the pumping station to the PSED is also made out by a telephone message. Transmitting managerial business information in this way has the following disadvantages:

- Responsibility for the uninterrupted transmission of information remains with the duty officer (the risk of exposure to the "human factor" is high);
- Incoming or transmitting information remains passive, i.e. the use of this information in the future is difficult because of the search for information by flipping through the registration log (for example, for compiling reports with comparative data of previous periods);
- It is not possible to provide a logical link between different documents, for example, the pumping station applies to the PSED for permission to temporarily stop work in connection with planned repairs, and the response telegram from the PSED may not refer to the telegram from the pumping station for permission.

To determine the efficiency of labor, the study of working time spent by employees of pumping stations was conducted by means of a questionnaire. An employee of the energy Department - an electrical engineer who plays an important role in monitoring electricity and preparing reports-was selected for the survey.

The following method was used to analyze the data obtained:

- grouping of work performed by employees by periodicity (daily, five-day, weekly, monthly, quarterly, annually);
- finding the average time spent on the execution of works for each period.

Analysis of questionnaires allows you to determine the type of work performed and the degree of employment of the employee in this work (Table 2).

Table 2. Analysis of working time spent by pumping station employees

Frequency of work performed	Time spent, %					
	Study of regulations and policy documents related to this work	Drawing up a document form, filling out a document	Counting and computing operations	The composition of the management letters, reports, etc.	Collecting or transmitting information	Meeting convened in person or by other persons
Daily	0	23.33	10	6.67	53.33	6.67
Five-day	0	0	10	10	70	10
Every decade	10	30	10	20	20	10
Monthly	0	0	0	20	60	10
Quarterly	0	0	0	10	70	10
Annually	0	0	0	10	70	10

The table shows that employees spend a lot of time collecting and transmitting information (53.33 + 70 + 20 + 60 + 70 + 70 = 343.33 - the largest number in specific weight), for creating emails, summaries (6.67 + 10 + 20 + 20 + 10 + 10 = 76.67), to a meeting convened in person or by other persons (6.67 + 10 + 10 + 10 + 10 + 10 = 56.67), on drawing up the form (23.33 + 30 = 53.33), on studying the standards, policy documents related to this work (10).

In general, the analysis carried out to determine the effectiveness of labor organizations showed that there is a significant waste of working time in pumping stations associated with performing routine work of collecting and transmitting the information.

Analysis of the existing system for monitoring electricity consumption and organizing work in pumping stations has shown many shortcomings:

- pumping stations do not automatically register the readings of measuring instruments and transmit them to computers for processing;
- readings are processed manually, which leads to a significant amount of working time;
- documentation is not unified (it contains a large number of different forms; terminology used in documents is not ordered, its unity is not observed; information in documents is often duplicated; there is a redundancy of information in documents, as well as the documents themselves), which leads to a significant waste of time by employees;
- business documentation is created mainly manually, by registering in various journals, which is why there is a late registration, as well as a significant waste of time associated with routine work;
- business information from the MWM to the pumping stations and back is transmitted exclusively over the telephone network, which is why there is a problem in the work associated with technical failures in the network and the risk of a "human factor" when receiving and sending information;
- low degree of managerial work automation;
- there is no single corporate or another computing network that covers all the pumping stations of the PSED and MWM.

These shortcomings can be eliminated by implementing an automated system for monitoring electricity consumption at pumping stations (ASMEC-PS) under the Ministry of water management of the Republic of Uzbekistan that facilitates the release of employees engaged in accounting for electricity, generating reports and transmitting data on electricity consumed (see Fig. 1).

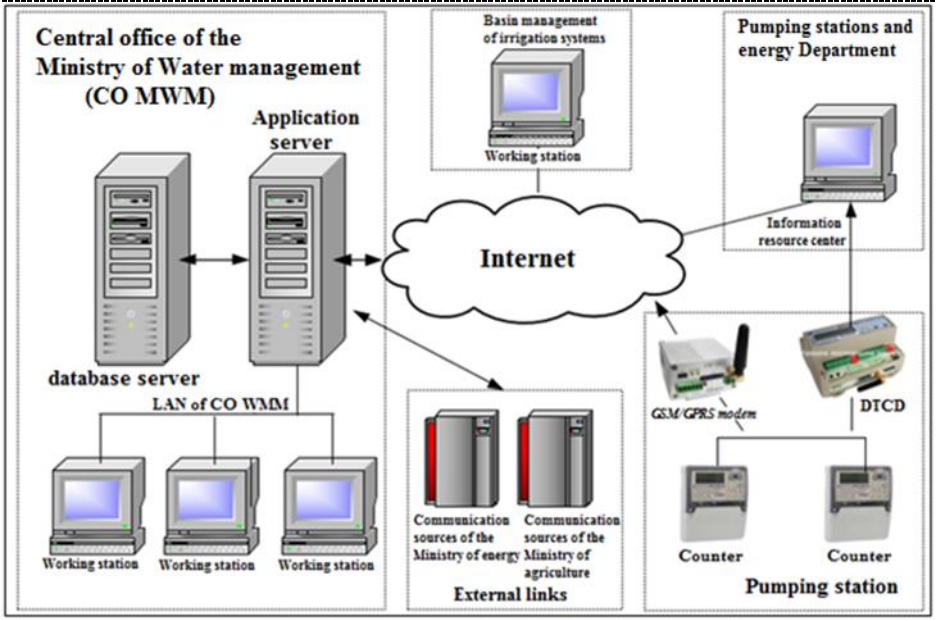

Figure 1. Scheme of information interaction of the main components of the system

The sources of economic efficiency of creating ASMEC-PS are:

- Reducing the consumption of electricity by pumping stations due to transparency and eliminating the "human factor" when accounting for electricity;

- Reduced labor costs through automation of work of the account of energy consumption, preparation of reports and data transfer;
- Increase productivity associated with the collection and processing of information, the formation of documents (including reporting), and their transfer, by reducing the number of routine work and data duplication. The creation of a single information base assumes the maximum possible human participation in the formation of documents. Most of the documents will be created automatically in and extracted from the database at the user's request;
- Increase the efficiency of decision-making by:

- promptly provide information about deviations from planned production indicators (energy consumption limits) to take the necessary measures to eliminate them;
- optimization of the process of operation of pumping units based on planned indicators (limit of electricity consumption, the volume of water lifting);
- Reducing salary costs by freeing up employees who are engaged in routine work on accounting for electricity, generating reports, and transmitting data.

Expected economic efficiency of creating ASMEC-PS according to the survey data:

- the average time for creating (forming, approving, approving) a single document without automating the document flow takes about 1 – 2 hours. The average time to create a document when implementing ASMEC-PS will be approximately 0.001 to 0.1 hours, i.e. the time to create a document is reduced from 10 to 1000 times;
- the average time for collecting or transmitting information to the PSED and in turn to the Central Office of the Ministry of water management (CO MWM) is up to 70% of the total time for creating (forming, approving, approving) a single document without automating the document flow. This is about 0.5 hours to 1 hour. The average time for collecting or transmitting information when implementing ASMEC-PS will be approximately 0.001 to 0.05 hours, i.e. the efficiency of collecting or transmitting information increases from 20 to 500 times.

The following economic efficiency is expected from automation when considering processes separately:

1. Reducing power consumption by pumping stations:

- Monitoring of tasks execution switching on/off of pumping units, automatic detection of non-fulfillment of the task, when the electric meter mode is automatically interrogated, it turns out whether the unit is working or not. This prevents unauthorized activation of pumping units.
- Automation of control over the implementation of the electricity consumption limit for the 25th day of the month and preparation of a proposal for making changes to the electricity consumption contract with TPP;
- Elimination of theft or inefficient power consumption. Automatic calculation of the power consumption balance in the pumping station will show how much energy is spent by the pumping units and how much is spent for other purposes;

2. Reducing labor costs (by automating tasks №2-17 in table 1):

At pumping stations:

- 100% removal of the electricity meter indicator, registration in logs, transfer to the PSED, because these functions are fully automated;
- 100 % on the preparation of the document "permission to change the limit", since the function is fully automated;
- 100% on daily, monthly and arbitrary reports on electricity consumption.

At PSED:

- 100 % preparation of daily summary data on electricity consumed by the PSED and transmission to the CO MWM, since the function is fully automated;
- 100% on the preparation of summary reports of daily, monthly and for any period of electricity consumption;
- 80% on setting the task for turning on/off the pump units.

At CO MWM:

- 100% on the preparation of summary reports of daily, monthly and for any period of electricity consumption;
- by 80% on the installation to allow changes to the electricity limit.

The savings from the operation of the ASMEC-PS are determined to take into account the costs of its operation. The ratio of these savings to the cost of creating a system characterizes the economic efficiency of capital investments.

The opacity of accounting for energy consumed by pumping stations leads to the formation of debts to the supplier of electric energy. In turn, a large debt leads to financial instability and forces you to take short-term loans from banks.

Uncontrolled unauthorized activation of pumping units (currently it is not possible to determine the inclusion of units), theft or inefficient electricity consumption (currently it is not possible to quickly draw up a balance of electricity consumption in the pumping station) lead to excessive spending. By installing the control with the help of ASMEC-PS, you can save at least 1% of electricity, i.e. 80 million kW·h per year. The annual savings amount will be:

$$\Delta C = \Delta E \cdot c = 80{,}000{,}000 \cdot 295 = 23{,}600{,}000{,}000 \text{ sum}$$

here: ΔE is the saved amount of electricity, kWh;

c is the cost of a kW·h of electricity, sum.

If ASMEC-PS is implemented, the savings in labor resources will be approximately 7% (1000 people for the PSED). The cost per person per year will be:

$$C_1 = (\text{SS} + SP) \cdot 12 = (2{,}000{,}000 + 240{,}000) \cdot 12 = 26{,}880{,}000 \text{ sum}$$

here: SS is the average staff salary, sum;

SP is the unified social payment, sum.

Therefore, the total cost per year for 1000 people will be:

$$\sum \text{C}_1 = C_1 \cdot 1000 = 26{,}880{,}000 \cdot 1000 = 26{,}880{,}000{,}000 \text{ sum}$$

in other words, the introduction of ASMEC-PS will save 26.88 billion sums per year due to labor costs.

Thus, the estimated annual savings from the implementation of ASMEC-PS will be:

$$\sum \text{C}_{year} = \Delta C + \sum C_1 = 23{,}600{,}000{,}000 + 26{,}880{,}000{,}000 = 50{,}480{,}000{,}000 \text{ sum}$$

The full cost of the development and implementation of ASMEC-PS will be:

$$Z = TM + SD = 6{,}824{,}000{,}000 + 2{,}720{,}790{,}000 = 9{,}544{,}790{,}000 \text{ sum}$$

here: TM is the cost of technical means, sum;

SD is the software development, sum.

The annual amount of operating expenses will be:

$$OE = I + S + MDT = 812{,}640{,}000 + 408{,}119{,}000 + 109{,}000{,}000 = 1{,}329{,}000{,}000 \text{ sum}$$

here: I is the annual cost of Internet services:

$$I = P \cdot M \cdot 12 = 40{,}000 \cdot 1693 \cdot 12 = 812{,}640{,}000 \text{ sum}$$

P is the cost of one package of Internet services, sum;

M is the number of modems, one for each pumping station;

S is the software support, 408,119,000 sum (15% of software development – 2,720,790,000 sum);

MDT is the maintenance of data transmission facilities 109,000,000 sums (15% of the original amount of delivery of modems and repeaters – (507 million sums + 220 million sums).

Therefore, the payback period for the creation and implementation of ASMEC-PS will be in months:

$$T = \frac{Z}{\sum C_{year}} \cdot 12 = \frac{9{,}544{,}790{,}000}{50{,}480{,}000{,}000} \cdot 12 = 2.5$$

4. Conclusions

Based on the research, the following conclusions can be drawn:

- a large amount of routine work on collecting, processing and transmitting information about planning and actual electricity consumption, and its presentation in the form of paper documents, which is performed by management personnel, leads to large unproductive costs of working time;
- low efficiency of obtaining the information to track (monitor) real-time power and decision-making on planning (on/off) of pump units;
- the opacity of accounting for electricity consumption and drawing up a balance of electricity consumption in a pumping station leads to unnecessary waste of electricity;
- the introduction of ASMEC-PS will prevent inefficient energy consumption in the process of "human factor" and save electricity;
- the introduction of ASMEC-PS economically feasible on other types of pumping stations such as water supply and water drainage.

References

[1] Robert L Sanks George Tchobanoglous B E 2008 Pumping station design *3d edn Elsevier Butterworth-Heinemann*
[2] Davydenko L Rozen V Davydenko V Davydenko N (2020) Control of operation modes efficiency of complex technological facilities based on the energy efficiency monitoring. *Lecture Notes in Mechanical Engineering*, pp 531-540
[3] Anon Computerised pump controller 1987 *Water Serv* **91** pp 210
[4] Owen A Brockway P Brand-Correa L Bunse L Sakai M Barrett J 2017 Energy consumption-based accounts A comparison of results using different energy extension vectors *Appl Energy* **190** 464–473
[5] Davydenko L Rozen V Davydenko V Davydenko N 2017 Formalization of energy efficiency control procedures of public water-supply facilities *Advances in Intelligent Systems and Computing* **543** pp196-202
[6] Hsu N S Huang C L Wei C C 2013 Intelligent real-time operation of a pumping station for an urban drainage system *J Hydrol* **489** pp 85–97
[7] Vologdin S V Shushkov I D Bysygin E K 2018 Portable data collection terminal in the automated power consumption measurement system *In Journal of Physics Conference Series.* Institute of Physics Publishing **944**(1)
[8] Chiang Y M Chang L C Tsai M J Wang Y F Chang F J 2011 Auto-control of pumping operations in sewerage systems by rule-based fuzzy neural networks *Hydrol Earth Syst Sci* **15** 185–196
[9] Shortall J O'Brien B Sleator R D Upton J 2018 Daily and seasonal trends of electricity and water use on pasture-based automatic milking dairy farms *J Dairy Sci* **101** pp 1565–1578
[10] Nguyen N H Tran Q T Leger J M Vuong T P 2010 A real-time control using wireless sensor network for intelligent energy management system in buildings In EESMS 2010 - 2010 IEEE *Worskshop on Environmental Energy and Structural Monitoring Systems Proceedings* pp **87–92**
[11] Kaya D Yagmur E A Yigit K S Kilic F C Eren A S Celik C 2008 Energy efficiency in pumps *Energy Convers Manag* **49** 1662–1673
[12] Kan E Ikramov N Mukhammadiev M 2019 The change in the efficiency factor of the pumping unit with a frequency converter In *E3S Web of Conferences EDP Sciences*
[13] Ikramov N Kan E Mirzoev M Majidov T 2019 Effect of parallel connection of pumping units on operating costs of pumping station In *E3S Web of Conferences EDP Sciences*
[14] Mamajonov M Bazarov D R Uralov B R Djumabaeva G U Rahmatov N 2019 The impact of hydro-wear parts of pumps for operational efficiency of the pumping station *J Phys Conf Ser* **1425** 012123
[15] Singh P Kansal A 2018 Energy and GHG accounting for wastewater infrastructure *Resour Conser Recycl* **128 499–50**7
[16] Reynolds L K Bunn S 2010 Improving energy efficiency of pumping systems through real-

time scheduling systems In *Integrating Water Systems - Proceedings of the 10th International on Computing and Control for the Water Industry* CCWI 2009 pp **325–329**
[17] Jorge Filipe Ricardo J Bessa Marisa Reis Rita Alves P P 2019 Data-driven predictive energy optimization in a wastewater pumping station *Appl Energ* **252**
[18] Shaazizov F Uralov B Shukurov E Nasrulin A 2019 Development of the computerized decision-making support system for the prevention and revealing of dangerous zones of flooding In *E3S Web of Conferences EDP Sciences*
[19] Bazarov D Shodiev B Norkulov B Kurbanova U Ashirov B 2019 Aspects of the extension of forty exploitation of bulk reservoirs for irrigation and hydropower purposes In *E3S Web of Conferences. EDP Sciences*
[20] Ergashev R Artikbekova F Jumabayeva G Uljayev F 2019 Problems of water lifting machine systems control in the republic of Uzbekistan with new innovation technology In *E3S Web of Conferences EDP Sciences*
[21] Khidirov S Berdiev M Norkulov B Rakhimov N Raimova I 2019 Management exploitation condition of Amu-Bukhara machine channel In *E3S Web of Conferences EDP Sciences*
[22] Shaazizov F Badalov A Ergashev A Shukurov D 2019 Studies of rational methods of water selection in water intake areas of hydroelectric power plants In *E3S Web of Conferences EDP Sciences*